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THE
Tea Research Institute
OF
Ceylon.

BULLETIN No. 3.

Annual Report for the Year
1928.



Published by

THE TEA RESEARCH INSTITUTE OF CEYLON,
VICTORIA COMMEMORATION BUILDINGS, KANDY.

THE TEA RESEARCH INSTITUTE.

BOARD OF CONTROL.

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The Hon'ble the Director of Agriculture.
The Chairman, Planters' Association of Ceylon.
The Chairman, Ceylon Estates Proprietary Association.
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Mr. J. D. Finch Noyes.
Mr. J. Horsfall.
Col. T. G. Jayawardena.
Mr. P. A. Keiller.
The Hon'ble Mr. J. W. Oldfield.
Mr. T. B. Panabokke.

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SCIENTIFIC STAFF.

Director :—T. Petch, B.A., B.Sc.

C. H. Gadd, D.Sc.	... Mycologist.
T. Eden, M.Sc., A.I.C.	... Agricultural Chemist.
D. I. Evans, B.Sc., Ph. D.	... Biochemist.
S. Stuart Light, A.R.C.S., D.I.C.	... Entomologist.

Laboratories :

The Tea Research Institute, Nuwara Eliya.

All communications concerning the scientific and advisory work of the Institute should be addressed to the Tea Research Institute, Nuwara Eliya.

REPORT

OF THE

Board of the Tea Research Institute of Ceylon FOR 1928.

Members of the Board:—On the 1st January, 1928, the Board of Management consisted of the following Members:—

Chairman:—Mr. R. G. Coombe.

Secretary:—Mr. A. W. L. Turner.

Ex-Officio Members.

1. The Hon'ble The Colonial Treasurer, (Mr. W. W. Woods).
2. The Director of Agriculture, (The Hon. Mr F. A. Stockdale).
3. The Chairman, P. A. of Ceylon, (Mr. Geo. Brown).
4. The Chairman, C. E. P. A. (Mr. W. Coombe).

Representatives of the P. A. of Ceylon.

5. Mr. R. G. Coombe.
6. Mr. John Horsfall.
7. Mr. D. S. Cameron.

Representatives of the C. E. P. A.

8. Mr. H. Hopwood, (Acting for the Hon'ble Mr. J. W. Oldfield).
9. Mr. F. E. Mackwood, (Acting for Mr. J. D. Finch Noyes).
10. Mr. P. A. Keiller.

Representatives of the L. C. P. A.

11. Col. T. G. Jayawardene, V.D.

Representative of the Smallholders.

12. Mr. T. B. Panabokka.

Mr. J. D. Finch Noyes and the Hon'ble Mr. J. W. Oldfield returned from leave on the 11th February and 7th March, 1928, respectively and resumed their seats on the Board forthwith.

Mr. Geo. Brown resigned the Chairmanship of the Planters' Association of Ceylon and was succeeded by Mr. E. C. Villiers on the 14th March.

The Chairman, C. E. P. A. (Mr. W. Coombe) and Col. T. G. Jayawardene proceeded on leave on the 23rd May, 1928, and the 5th September, and were succeeded respectively by Mr. H. F. Parfitt and the Hon'ble Mr. D. S. Senanayake.

The Hon'ble Mr. F. A. Stockdale resigned his appointment as Director of Agriculture in November. He was succeeded on this Board by Dr. W. Small in his capacity as Acting Director of Agriculture.

Meetings of the Board:—During the year four Ordinary and two Special Meetings of the Board were held. The average attendance was 8.

Buildings Sub-Committee:—A Buildings Sub-Committee was appointed on the 30th May, 1928.

Personnel:—Mr. R. G. Coombe (Chairman), The Hon'ble the Director of Agriculture, The Director of the Institute, Mr. P. A. Keiller and Mr. J. Horsfall.

This Sub-Committee met on two occasions.

Estate Sub-Committee:—An Estate Sub-Committee was appointed on the 23rd March, 1928.

Personnel:—Mr. R. G. Coombe (Chairman) The Hon'ble Mr. J. W. Oldfield, Messrs. D. S. Cameron, John Horsfall and J. W. Ferguson.

The last named in his capacity as Visiting Adviser was invited to join the Committee (Sec. 12 (1) Ord. No. 12 of 1925).

This Sub-Committee met on six occasions.

The Board wishes to record its thanks to the Ceylon Chamber of Commerce for the use of the Committee Room for the Meetings held in Colombo.

Scientific Staff:—

	Date of commencing duties in Ceylon.
<i>Director:</i> —Mr. T. Petch, B.A., B.Sc.,	8th March, 1926.
<i>Mycologist:</i> —Dr. C. H. Gadd, D.Sc.	1st July, 1926.
<i>Agricultural Chemist:</i> —Mr. T. Eden, M.Sc., A.I.C.	18th Octr., 1927.
<i>Bio-chemist:</i> —Dr. D. I. Evans, B.Sc., Ph.D.	6th Septr., 1926.
<i>Entomologist:</i> —Mr. S. Stuart Light, A.R.C.S., D.I.C.	17th May, 1926.

Mr. T. Petch proceeded on six months' furlough on 9th October, prior to retirement.

Dr. C. H. Gadd was appointed Acting Director on the 8th October, until such time as a new Director is appointed.

Dr. Gadd's agreement was renewed for a further period of five years as from the 30th June, 1929.

During the year the Laboratory Staff was strengthened by the appointment of Mr. A. T. Wirasinha as Assistant to the Chemists on the 1st July, 1928, and Mr. D. J. William as Assistant to the Entomologist on the 1st August.

Dr. D. I. Evans proceeded on 12 weeks' emergency leave out of Ceylon on the 5th December.

Laboratories:—The research work of the Institute continued to be carried out in the temporary laboratory at "Lindfield," Nuwara Eliya, the lease being renewed for a further period of one year from the 1st July, 1928. The Bungalow on Mahagalla Estate, Maskeliya, was also rented for one year from 15th June to enable the Entomologist to carry out experiments in connection with Tea Tortrix.

Experiment Station:—In December the Board purchased St. Coombs Estate for Rs. 600,000/- from Messrs. The Anglo-Ceylon & General Estates Co., Ltd. The approximate extent of the Estate is 425 acres made up as follows:—

Tea in full bearing.....	185 acres
Tea clearings }	240 acres
Patna, swamp }	
	<u>425 acres</u>

Mr. J. W. Ferguson has been appointed Visiting Agent and Mr. J. A. Rogers, Superintendent of the Estate.

The erection of the following Buildings will be carried out as expeditiously as possible :—

1. Factory.
2. Laboratory.
3. Director's Bungalow.
4. Superintendent's Bungalow.
5. Five Bungalows for Senior Scientific Staff.
6. Four Bungalows for Subordinate Scientific Staff.
7. Two Bungalows for Estate Subordinate Staff.
8. 40 Rooms in Cooly lines.

Finance:—In order to finance the Experiment Station, the Board obtained a loan of Rs. 1,000,000/- from the Ceylon Government at 6% interest. This sum is to be repaid by 25 annual instalments of Rs. 78,227/-. The repayment of the first instalment will be due to be made on the 29th. September, 1929.

The Statements of Accounts and Balance Sheet are attached.

Publications:—During the year Bulletin No. 2 (Annual Report for 1927) and Vol. 1 (4 parts) of the "Tea Quarterly" were issued. Free issues of these publications were made to all registered Superintendents and Proprietors of Tea Estates. Additional copies can be sent also free, to all Assistant Superintendents of Tea Estates on application to the Secretary.

The annual subscription for other persons desirous of receiving the Institute's Publications is Rs. 15/- for those resident in Ceylon or India, and £1-5-0 elsewhere. The register of those who received the Publications during the year contained 1,105 names as compared with 1,026 last year.

Future Policy:—As soon as the necessary buildings have been erected on St. Coombs Estate the Scientific Staff will be increased from time to time as funds permit.

The ultimate aim is to establish small Sub-Stations in various parts of Ceylon as necessity arises.

The part of the Estate already opened, not required for experimental work, will be developed on commercial lines. It is intended to plant up the unopened part of the Estate into Tea during the next five years commencing from 1930. Allowing say 40 acres for Research purposes and 45 acres for buildings, swamps, etc., the profit yielding area will, in course of time it is hoped be 340 acres.

A. W. L. TURNER,
Secretary.

REPORT

OF

THE ACTING DIRECTOR

TEA RESEARCH INSTITUTE OF CEYLON,

FOR 1928.

Laboratory:—An additional working room in the temporary laboratory at Nuwara Eliya has been fitted with gas and water and furnished as an additional laboratory for the Chemists. The accommodation provided by this building is now fully occupied.

Mahagalla bungalow in the Maskeliya district has been rented for the use of the Entomologist and to serve as a laboratory for the breeding of an egg parasite of the Tortrix moth. The Entomologist has been stationed there since July 1st.

Plans of permanent laboratories to be erected on St. Coombs Estate have been prepared. The buildings, when completed, will provide ample accommodation for all divisions.

Library:—Mr. J. R. Neale has kindly presented to the Institute library Volumes XXIII (part) and XXIV of *The Tropical Agriculturist*, and Messrs. George Steuart & Co., 19 Volumes of the same journal covering the period 1882 to 1904. Several periodicals, including many publications from Java, have been received from the Planters' Association of Ceylon. These are very welcome gifts and valuable additions to the library. As previously announced, the Institute would be grateful for any copies of old books and pamphlets relating to tea, for which the owners have no further use.

A list of the additions to the library made during the year is appended.

Tea Quarterly:—In *The Tea Quarterly*, of which the first volume, consisting of 122 pages and 9 plates, has been published, the Institute now has a journal, by means of which the work of the scientific staff may be brought to the notice of Ceylon Tea Planters. In addition to articles by the staff dealing with their investigations in the laboratory or the field, the journal aims to provide a summary of available information relating to the cultivation and manufacture of tea, and to fill a gap which at present exists in the agricultural literature of the British Empire. Contributions, dealing with actual experiences and results obtained in practice, would be welcomed from our planting readers.

This journal is supplied free of charge to Superintendents of Ceylon tea estates, over ten acres in extent, and to Estate Agencies dealing with Ceylon tea, if they register their names and addresses with the Secretary.

Agricultural Conference:—The Director read a paper on "Some problems of the Tea Research Institute" which was followed by an interesting discussion, at the Third Agricultural Conference at Peradeniya in May last. Contributions to other important discussions, Branch Canker, The Relationship between Manuring and Callus formation in Tea, The Results of Drainage and Leaching Trials at Peradeniya during 1927, Cover Crops and Green Manuring, and *Rhizoctonia bataticola*, were made by the Director, the Agricultural Chemist and the Mycologist. In the absence of the Mycologist his notes were read by Mr. Petch.

Acknowledgements:—The thanks of the Institute are tendered to the Managers and Superintendents of the many estates, who have so willingly co-operated with the staff and facilitated their work by supplying information and material for research purposes; to Messrs. Keel & Waldoek for testing samples of tea; to the Department of Agriculture for the loan of literature, and its staff for their co-operation; to the Superintendent of the Colombo Observatory for placing a Campbell-Stokes Sun Recorder at our disposal; to Mr. C. D. Sparkes, Manager, and to Messrs. M. H. Robinson and G. L. Lushington, Superintendents of The Scrubs Estate for their help in conducting the Uniformity Trial.

Staff.

Mr. T. Petch departed on leave preparatory to retirement on October 6th, and the writer assumed duties as Acting Director. During his 23 years in Ceylon, Mr. Petch acquired a unique knowledge of the many problems which face the tropical agriculturist. His reputation as a mycologist is world wide, and his opinion is sought from all quarters of the globe. He has a great fund of accurate information, not only on mycological matters but concerning all the sciences allied to agriculture, which was always freely at the disposal of his staff and the planting community. On Mr. Petch's departure, Ceylon parted with a good friend and one who has done much for tropical agriculture. We wish him many years of health and happiness in which to enjoy the rest he richly deserves after his many arduous years of work in and for Ceylon.

No further addition was made to the senior research staff during the year. A start has been made in the formation of a subordinate research staff by the appointment of Messrs. A. T. Wirasinha and D. J. William, as assistants to the Chemists and Entomologist, respectively. Mr. Wirasinha took up duties on July 1st and Mr. William on August 1st.

Work of the Staff.

For several years it has been fully recognised by those intimately associated with field experimentation, that the data obtained from field experiments must be subjected to statistical examination before valid conclusions can be drawn from them. The application of statistical tests cannot transform a poor experiment into a good one; no amount of statistical calculation can take the place of original data. If through faulty design, an experiment is liable to large errors resulting from soil heterogeneity or other chance factors, the use of statistical methods cannot eliminate those errors though it may enable their values to be estimated.

The association in recent years of mathematicians with field experimenters has led to the development of statistical methods specially suited for field experimentation. General principles, applicable to most crops,

have been established, but methods applying the principles to particular cases have still to be developed. Tea differs from the majority of agricultural plants in that its crop is harvested throughout the year, and in that its cropping period varies from eighteen months to four years, dependent upon the length of the pruning cycle. For such reasons, the technique applicable to annual crops cannot be applied to tea without adjustments. Certain fundamentals have to be determined before field experiments with tea can be designed to meet modern requirements. What is the best size of plot for experiment? How many replications are necessary to reduce experimental errors to a requisite small size? And so on.

A start has been made to obtain this information by means of a Uniformity Trial on The Scrubs Estate, Nuwara Eliya. This experiment consists of 144 plots covering an area of 2 acres, and all are treated alike. It is not expected that this trial will supply information of much interest to the practical planter, but it will provide important and necessary data for the scientific staff responsible for the design of future experiments with tea. The experiment is of the nature of fundamental research, essential for the planning of future experiments on sound lines, in order that when completed, such experiments will give accurate answers to the questions they are designed to answer. So many field experiments in the past have failed to give requisite answers; or where given, there has been some uncertainty about them. If sure and rapid progress is to be made, our field experimentation must be founded on sound principles.

The data obtained from the experiment have been carefully examined by the Agricultural Chemist, who has drawn, in his report, a number of important conclusions concerning the design and management of experiments involving yield measurements. These and other principles derived from these investigations will be applied when designing experiments to answer specific questions.

The Uniformity Trial is being used for other purposes as well as those indicated above. Samples of leaf from each plucking are analysed by the chemists in the laboratory. The analyses furnish the Soil Chemist with important information regarding the uptake of manurial substances from the soil by the tea bush, and the Biochemist with data concerning the variation in the chemical constituents of the leaf throughout the year.

A complete understanding of the chemical processes which take place during manufacture is dependent upon a knowledge of the chemical composition of the raw material which comes into the factory. The composition of fresh leaf varies not only from season to season, but also during the day. Under certain conditions the leaf plucked during the afternoon is chemically different from that plucked during the morning, and, if kept separate, would probably result in a different quality of made tea.

The variation of the raw material, as it comes into the factory, naturally causes variation in the quality of the manufactured teas. The valuation of the made tea depends upon many factors, of which the taste of the infused liquor is not the least important. What are the chemical substances which give the desired flavour to tea and from what constituents of the fresh leaf are they derived? These are complex problems and much patient research is necessary to solve them.

A knowledge of the raw material which comes into the factory and an understanding of the desirable and undesirable constituents of made tea are but the two ends of the problems of manufacture. Between lies the changes which occur during the processes of manufacture and the determination of the effect of each process on the composition of the leaf. Before these can be studied intelligently, from the chemical standpoint, a knowledge of the constituents of the raw materials and of the desired end products of manufacture is essential. Systematic analyses are necessary to provide the data from which these and similar problems can be solved. The necessary data are steadily being accumulated, from which important, though tentative, conclusions are drawn by the Biochemist in his report.

The Entomologist, since July, has been stationed in the Maskeliya district at Mahagalla bungalow, in order to facilitate the study of Tortrix and the parasites which attack it. Work has been concentrated on the breeding of a parasite (*Trichogramma erosicornis*) which attacks the Tortrix egg masses and destroys them. This parasite occurs naturally on several estates, but its numbers are kept down by certain natural agencies. By breeding the parasites in the laboratory under favourable conditions, it is hoped to raise a colony of such a size that hundreds of thousands of parasites may be distributed to infected estates and liberated daily.

Numerous difficulties have been met with in this work, but as these are overcome, and when the colony is sufficiently large to allow of suitable field experiments, the efficiency of the parasite as a means of controlling Tortrix will be tested. Small laboratory experiments have shown that when liberated the parasite will find and attack Tortrix egg masses.

The use of insecticidal and fungicidal sprays is very much restricted by the nature of the tea crop. The value of certain non-poisonous spray fluids in the control of insect pests is being investigated by the Entomologist. Not only has the effect of the spray on the insect to be determined, but the effect of the fluid on the tea, made from the leaf plucked from the bushes after treatment, has to be ascertained. Trials have been made to ascertain to what extent such tea would be tainted. The fact that, of six samples made from untreated bushes, three were reported to be tainted, indicates the difficulties of carrying out accurate experiments on this problem.

The value of lime when applied to the soil in tea cultivation is a controversial subject. Experiments to determine its value have given contradictory results on different soils. This is probably due to the fact that different soils react in differing degrees to equal additions of lime. The application of lime to the soil results in a change in its reaction, the soil becomes less acid or more alkaline, and it is this effect which influences the growth of tea. Pot experiments with seedlings have demonstrated that, with the soil used, the optimum degree of soil acidity lies between 5.3 and 6.5 in the pH scale. Higher values had a marked detrimental effect on the seedlings, and led to the development of pathological symptoms resembling those characteristic of the Witches' Broom of mature bushes. Values lower than 5.3 were not so harmful.

The work of the Agricultural Chemist on this subject indicates that the relationship of soil acidity to the growth of tea is by no means simple, as soil acidity is connected with the physical and physico chemical properties

of the soil. Alkaline soils and many which approximate neutrality will not support healthy tea, but the optimum degree of acidity for tea probably varies with the type of soil.

Lime has been extensively used in the past in the treatment of fungus root diseases. Observations in the field and experiments in the laboratory indicate that its value for this purpose is not great. As far as *Poria* root disease is concerned, it has been demonstrated that the application of lime, instead of retarding the growth of the fungus, increases its rate of growth. Lime should, therefore, not be used in the treatment of this disease.

A previously unrecorded disease of dadaps has been investigated and found to be due to the attacks of a small eelworm (*Heterodera radiculicola*) which causes large galls on the roots. The failure to grow dadaps successfully over large areas is a result of this disease. Fortunately, mature tea bushes appears to be immune to the attacks of this parasite, although seedlings are very susceptible.

The discovery that the tea bushes, which die after pruning of the *Diplodia* disease, are destitute of starch has thrown a new light on the causation of this disease, and offers a simple explanation why such bushes die after pruning. The disease is not the result of attacks by parasitic fungi, as was previously supposed, but is the direct consequence of the depletion of the bush's food reserves. The application of fertilisers at pruning time cannot remedy the deficiency, so preventive treatment must be directed towards the conservation of internal food reserves.

Reports of the scientific officers are appended.

C. H. GADD,
Acting Director.

REPORT OF THE MYCOLOGIST.

Advisory:—Four hundred and ninety one letters have been received and three hundred and seventy three despatched. Two hundred and one consignments of diseased plants have been received for examination and report. Of these, one hundred and sixty three were tea; the remainder consisted of *Acacia*, *Albizzia*, *Dadap*, *Grevillea*, *Gliricidia*, *Hibiscus*, *Lupin* and *Tephrosia*. Of the tea consignments, 75 were diseases of the roots, 12 of stems, 50 of leaves, 19 of seedlings and 7 were miscellaneous diseases.

Visits have been made to 31 estates in the Badulla, Bandarawella, Bogawantalawa, Dickoya, Dimbula, Dolosbage, Haldumulla, Hewaheta, Kadugannawa, Kotmale, Maskeliya, Nuwara Eliya, Opanaika and Uda-pussellawa districts.

An address was given to the Dolosbage and Yakdessa Planters' Association in June on "The treatment of root diseases." The address was published in the daily press.

TEA.

Root Diseases.

Poria:—The disease caused by *Poria hypolateritia* continues to be the commonest root disease of tea in upcountry districts; it is also the most difficult to eradicate. The importance of the removal of all roots and woody matter is generally recognised, but it is not fully realised, when treatment is undertaken, that usually the fungus has progressed beyond

the last line of dead bushes and has established itself on the roots of adjacent apparently healthy bushes. Unless the attacked roots of living bushes are removed, the fungus continues to grow actively, and the area of the infected patch increases annually.

The construction of trenches around an infected area does not always prove an efficient means of preventing further progress of the pathogenic fungus. In some cases, failure is due to placing the trenches in the wrong position; the fungus has passed the trench line before the trenches are dug. More frequently, failure is the consequence of frequent silting up and the delay in emptying the trenches. In view of the long time the trenches have to be kept open, particularly when dead bushes only are uprooted, the failure of the trenches to stop the progress of the disease is not surprising. On hill-sides where *Poria* infected areas are numerous, the complete removal of a belt of perfectly healthy tea round each area may be necessary as a substitute for, or in addition to, the trenches, where the construction of the latter is practicable.

The futility of supplying infected areas, while the disease is active on the perimeter, is becoming recognised. Where such areas are supplied, the young plants normally do well for two or three years before they succumb. *Poria* disease is unknown on young seedlings, and it is probable that tea plants are immune from this fungus until they are two or three years old. The failure of supplies may be due to the fungus growing inwards through the area from the attacked plants on the perimeter, or to an ability of the pathogen to live independently in the soil and apart from such obvious food supplies as woody tissues.

Small *Poria* patches, replanted after the dead bushes had been dug out, have been examined in young clearings. The supplies were found to be attacked by the same disease, though no further deaths had occurred in the original planting. In these cases, infection probably occurred direct from the soil, not from the infected roots on the perimeter of the area. Unfortunately, no record had been kept of the interval elapsing between the uprooting of the original infected plants and the replanting with supplies.

Generally, it is advised that infected areas should be left bare for at least 12 months after the last diseased bush has been removed, before supplying. This period has been determined mainly from field observations and possibly on the assumption that the fungus feeds only on incompletely decayed vegetable matter. In the laboratory, the fungus *Poria hypolateritia* has been found to live for several months on finely sieved soil from which all undecayed vegetable matter had been removed. The soil was sterilised and inoculated from pure culture; the inoculum was removed after growth started, in April. At monthly intervals, samples of the soil were removed from the flasks and placed on a suitable sterile culture media in tubes. Growth occurred in all the tubes inoculated previous to and including December 20th. It was evident, therefore, that *Poria* could live for at least 8 months under the conditions of the experiment, which in some respects, are more severe than those occurring naturally in the field.

The removal of all infected roots is insufficient to eradicate the pathogenic fungus from the soil. The treated area must be kept bare for some time before it is supplied with young plants. Further experiments are necessary to determine the length of this period under different conditions and for different soils.

Experiments have been made to determine the rate of growth of *Poria hypolateritia* through soils of various reactions, a short account of which is given in *The Tea Quarterly* Vol. II part I. The most rapid growth occurred in the soil to which lime had been added at the rate of 5 tons per acre. Even 15 tons of lime per acre caused no diminution in the growth rate as compared with that in the untreated soil. It may be concluded, therefore, that lime has no beneficial effect in the treatment of this disease; in fact it is more likely to favour the growth of the fungus than to retard it, so its use should be discontinued.

Brown Root and Ustulina diseases:—Relatively few cases of these diseases have been recorded during the year. Invariably, the diseases originated from adjacent jungle stumps in new clearings or from stumps of *Grevillea* left in the ground after felling. Routine stumping has resulted in a diminution of the incidence of these diseases.

Armillaria fuscipes:—This fungus which is regarded by Petch (*Brit. Myc. Soc. Trans.* Vol. XIII, p. 240) as the tropical analogue of the European species *A. mellea*, was recorded in the last Annual Report for the first time, as a disease of young tea plants and mature tea bushes in Ceylon. Since then, the same fungus has been found in three up-country districts to attack and kill mature tea bushes. *Armillaria* has been known for some years as an important root disease of tea in Java, and has recently been reported as a tea disease from Nyasaland.

The symptoms observed in Ceylon are similar to those described from Java and Nyasaland, though the splitting of infected roots is not an invariable characteristic. The peculiar cracks, which occur in infected roots of *Albizzia lophantha* and young tea plants, have not been prominent in the specimens of mature tea recently examined. In one instance, a deep longitudinal crack developed in a tap root on drying; roots attacked by other fungi have not been observed to split in this manner on drying.

Infected roots invariably show cords or sheets of mycelium in the cortex or on the surface of the woody cylinder. Black rhizomorphs, resembling small roots about 1/10 inch in diameter, characteristic of *Armillaria*, have been found on all specimens yet examined. The rhizomorphs are brittle; consequently, small fragments only remain attached to the tea bush when uprooted. No fructification has yet been found on tea in Ceylon, nor have any developed on roots in culture in the laboratory.

As yet the disease has proved of little economic importance in Ceylon, and treatment other than the uprooting of diseased bushes and the adjacent stump has been unnecessary. The association of this disease with old stumps affords another reason for the continuance of the stumping policy adopted by the majority of estates.

Rosellinia:—A further case of *Rosellinia arcuata* in nursery beds has been recorded. The nurseries were till recently virgin jungle and had been planted in gums before being used for tea.

Recent investigations have disclosed the fact that in Java this disease occurs only in soils with definite chemical characters. To what extent the same holds true for Ceylon soils is being determined in co-operation with the Agricultural Chemist. Samples of soil from *Rosellinia* infected areas have been collected and are being examined with this object.

PLATE I.



WOODROT — UNSUCCESSFULLY TREATED.

Experiments, similar to those referred to under the heading, Poria disease, have been carried out to determine how long Rosellinia is capable of living independently in soil containing no undecayed vegetable matter. Similar results have been obtained, and the fungus is still alive.

Diplodia disease:—It is very probable that several distinct diseases are known by the name Diplodia, but it is doubtful whether all are caused by the fungus *Botryodiplodia Theobromae*. In the mid and low country tea areas of Ceylon, a large number of tea bushes fail to recover after pruning, and the Diplodia fungus is commonly to be found on their roots. It is to this form of disease that the name Diplodia is usually applied in Ceylon, and to which the following observations refer.

This form of the Diplodia disease of tea is always associated with the absence of starch reserves in the roots. Tea normally stores its food reserves within the root, so the absence of stored supplies in this region is of significance. The absence of food reserves is sufficient, in the writer's opinion, to account for the death of the bushes after pruning without the assistance of any pathogenic fungus. An account of this view of the causation of the disease has been published in *The Tea Quarterly* Vol. I, pp. 89—93, to which reference should be made:

Chemical analyses have demonstrated that not only are the diseased roots destitute of starch, but that they are deficient in sugars also. The following figures illustrate the differences observed between healthy and diseased bushes:—

	Sugar %	Starch %	Total %
1. Healthy—normal recovery from pruning	4·16	3·21	7·37
2. Alive—slow recovery	0·21	0·49	0·70
3. Diseased—Diplodia	0·	0·07	0·07

The three bushes to which these analyses refer, were taken from the same field and within close proximity to each other. The field was about due for tipping when the bushes were uprooted for analysis. Bush No. 2 had no new shoots though one or two buds were breaking; bush No. 1 had recovered well, whereas No. 3 had died since pruning. The analyses are of the wood of the tap root.

The marked correlation between the amount of food reserves in the roots and the recovery from pruning has directed attention to the importance of elaborated food supplies within the root at pruning time, and has led to a new line of treatment for the Diplodia disease. If losses after pruning are to be prevented, the bushes must be allowed an opportunity to accumulate elaborated foods ready for use, to meet their requirements at that time.

The subject may have a direct bearing on the present tendency to force the tea bush into heavy yield without consideration of its effect on other vital characters of the bush. At low elevations, where climatic conditions tend to force the bush into leaf to the detriment of the accumulation or at the expense of food reserves, deaths following pruning are most numerous. It is possible that the same result may be obtained by forcing the bush to excessive leaf production by improper manurial stimulations.

Stem Diseases.

Wood rot or Branch Canker:—The treatment of this prevalent disease is occupying the attention of many estate managers, and a number of successful and instructive experiments have been carried out. Unfortunately, curative treatment is not practicable on all estates, as where the bushes are severely affected yet give good yields, the treatment would probably cause a greater diminution of crop than the disease does.

If the treatment aims to be curative, it is essential that all the infected wood must be scraped out of the canker. The removal of obviously rotted wood only is insufficient; all the discoloured wood and even apparently healthy wood into which the fungus has entered must be removed. This necessitates hard and deep scraping, and there is no simple criterion by which can be judged the complete removal of infected wood. Failure to remove all infected wood has resulted in more disappointing results than has the inefficiency of protective coverings applied after the wounds have been cleaned.

Three years ago, the manager of an estate in the Badulla district started an experiment on the treatment of cankers in lateral branches. The cankers were scraped out thoroughly with specially adapted shoeing knives, at considerable expense, and the cleaned surfaces were covered with a mixture of gas tar and Skene's wax. The writer examined the bushes soon after treatment and again when the bushes were pruned this year.

The experiment proved particularly successful and a very high percentage of cures was attained. The majority of the wounds had healed remarkably well and the cleaned wood had remained sound. It is not suggested that the tar and wax encouraged the healing process in any way, but the experiment demonstrated clearly that tar and wax is not detrimental to callus formation as is sometimes stated. In fact the healing was better than any the writer has seen elsewhere.

The tar and wax cover resisted weathering remarkably well, and satisfactorily prevented re-infection. Where treatment was not entirely satisfactory it was due to the leaving of infectious wood within the wound. The cankers, which, owing to their small size and convenient shape for scraping, were easiest to treat, gave the best results.

The scraping of the wounds was very thoroughly done; in fact, at first it was thought to be excessive as many branches were mechanically weakened. The development of new wood on the underside of the branches has so strengthened them, that now there is no risk of breakage. The failure to entirely clean out the infected wood from all the cankers treated, even after such severe scraping, illustrates the difficulties encountered when attempting curative treatment.

On another estate in the Kadugannawa district the Manager has carried out curative treatment, mainly in the crowns, with success for several years. The cavities are first thoroughly scraped out, painted with a mixture of Skene's wax and tar, and then filled with 'sandstone' before being finally painted with the mixture.

Fields, which have been so treated two years ago, are now comparatively free from scavenging termites. The termites are associated only with those bushes in which the treatment has been unsuccessful and where wood

PLATE II.



WOODROT — SUCCESSFULLY TREATED.

rot has continued below the filling. In every case examined, the termites indicated the existence of a canker which had not been treated or which had continued to rot after treatment.

Detailed examination was made of a number of bushes. In plate I is reproduced a photograph of a section through a treated bush, taken nine months after treatment. The excavated cavity was $6\frac{1}{2}$ inches deep. The wood on examination was seen to be discoloured, which indicated an incipient stage of decay. A section through another bush, taken two years after treatment, is shown in plate II. Here the treatment has obviously been successful. The treated cavity was 5 inches deep and the surrounding wood was sound, with no discolouration, when examined.

That complete cure can be attained after thorough cleansing of the cankers has been demonstrated. The removal of all infected wood is the key to the treatment; without this, cure is impossible. Unfortunately, in Ceylon, the idea has become prevalent that the promotion of callus formation or healing of wounds will automatically arrest the progress of decay within the wound. Such a theory is entirely fallacious as the two processes, healing and decay, are unrelated and can proceed independently. If one process can stop the other, it is the decay which stops the healing, as it is by no means uncommon to find dying back, callus growths which have formed over rotting wood. Wounds may completely heal over, yet the decay which started before the healing was completed continues, and the stem tends to become hollow.

It follows that treatment designed to promote callus formation will not prevent the entry of wood destroying fungi into fresh pruning cuts. These should be protected by an antiseptic cover such as tar, tar and wax or white lead paint, which will resist weathering. Bordeaux mixture which is being used on many estates is valueless for this purpose, as it is washed off by the first heavy rains.

Macrophoma Canker:—Several cases of the true branch canker, caused by the fungus *Macrophoma theicola*, have been investigated. In some cases, the attacked branches have also been infected by Red rust (*Cephaleuros parasitica*). *Macrophoma* so weakens the branches that they become liable to attack by Red rust. Such branches must be pruned out below the canker, not merely below the rusted patches. So far, *Macrophoma* canker has been found only in the low-country.

Diebacks:—In some districts, diebacks after pruning are very prevalent. In severe cases, the bush has the appearance of an early stage of the *Diplodia* disease, but examinations of the root system have disclosed the presence of abundant starch. It is a significant fact that such diebacks occur where shot hole borer is very prevalent; the dieback branches are usually riddled by the borer. As the borer frequently enters the stem at or just below a bud, it appears probable that the bud or the channels along which food materials are conveyed to the bud are damaged, and the bud is rendered incapable of further growth. An examination of a number of diebacks after pruning revealed the presence of shot hole borer galleries immediately below the buds which failed to develop. In such cases it seems probable that the diebacks are the direct result of shot hole borer attack.

Leaf Diseases.

Phoma theicola:—During the early months of the year, particularly March which was very dry, diseased leaves with which were associated the fungus *Phoma theicola* were submitted from several estates for identification. This fungus has never proved itself to be the cause of a serious disease but its increased incidence during drought is of interest.

Cercospora:—Very few outbreaks of the disease caused by *Cercospora theae* have occurred during the South West Monsoon this year, and these, like the monsoon conditions themselves, were relatively mild. This is in marked contrast with what happened last year, and lends support to the conclusion, previously drawn, that the virulence of the disease is dependent to a large extent upon climatic conditions.

Fructifications, similar to those found in pure culture and reported in Bulletin No. 1, were found on tea leaves which had remained attached to the stem, though killed by *Cercospora*. Unfortunately, the fructifications were empty and no spores could be found, so accurate identification was impossible.

Corticium vagum:—A leaf disease occurred on an estate in the Kalutara district, with which was associated the vegetative stage of the fungus *Corticium vagum* (*Rhizoctonia solani*). In some cases entire leaves were killed; in others, the injury was restricted to large areas of the leaf surface. The diseased areas turned brown or greyish brown and were not altogether unlike brown blight except that the diseased areas were not zoned. The fungus formed a web mainly on the lower surface of the leaf. When the leaves were placed loosely in an envelope for transmission, the mycelium caused the leaves to adhere together, and twenty four hours later, the leaves had to be torn apart. In this respect the disease resembles Black rot which is caused by *Corticium invisum*.

The mode of attack is also similar to that of Black rot. The fungus is essentially a soil fungus, and it reaches the leaves via the stems, and leaf stalks. For this reason, affected bushes should be pruned back and the prunings burnt. The stems and soil should then be sprayed with bordeaux mixture.

Although *Rhizoctonia solani* is a common fungus in Ceylon soils and frequently causes disease, particularly of Vigna (*Dolichos Hosei*) it has been recorded but once previously on tea in Ceylon. Then (1927) it occurred on tea seedlings also in the Kalutara district.

Inoculation experiments on tea seedlings were carried out in the laboratory at Nuwara Eliya with pure cultures of the fungus isolated from tea. The experiments were not successful; neither leaves nor stems were affected by the fungus. These results, however, cannot be regarded as conclusive, as it is well known that environmental conditions have an important bearing on the parasitism of this fungus. The field evidence is strongly in favour of the fungus being the real cause of the disease.

Galls:—Two further cases of galls or blister like swellings on the leaves of seedlings have been recorded during the year. Each gall is a result of the multiplication of the internal cells of the leaf, which gives rise to a mass of tissue resembling a blister up to $\frac{1}{2}$ inch in diameter and $\frac{1}{8}$ inch

thick. The upper surface of the intumescence is usually bright yellow and shows up in marked contrast with the normal dark green of the rest of the leaf; in some cases, the gall turns red, and in others it remains green.

No trace of fungus growth could be found in the tissues. Attempts to cause a similar condition on the leaves of healthy seedlings growing in the laboratory, by means of expressed juice from diseased specimens, failed. Diseased seedlings showing the characteristic swellings on the leaf were transplanted into pots and grown in the laboratory, but no further infections occurred. The new leaves developed by the diseased seedlings were healthy. The cause of the disease is obscure, but from the laboratory experiments and observations in the field, the disease does not appear to be infectious.

Many theories have been advanced elsewhere, after detailed study, to explain the formation of intumescences on plants other than tea. The most favoured theory is that an excessive water supply, accompanied by some other factor, such as an abnormal rise in temperature, is the main cause. The first case of this disease in Ceylon, reported last year, occurred after abnormally heavy rainfall, but the recent cases have not been associated with heavy rainfall; in fact, one occurred during a period of drought.

The majority of affected plants appear to recover; the affected leaves ultimately fall off and later developed leaves are healthy. Such plants have been put out in the field and are reported to be doing well. Although the disease does not appear to be of a serious nature, further outbreaks should be reported to the Institute as, apart from scientific interest, it would appear advisable to keep the disease under observation till more is known regarding its cause and nature.

Physiological.

Soil Cultures:—Experiments have been made to determine the effect of soil reaction on the growth of tea seedlings. Brief reference only need be made here, as a full account of them has been published recently (*The Tea Quarterly*, Vol. II, part 1, Feb., 1929.) Tea seedlings were grown in soils of different reactions. Lime and sulphur in varying quantities were used to cause the requisite alterations in reaction. The addition of lime at the rate of 5 tons per acre had a beneficial effect on the aerial growth of the seedlings, but heavier applications resulted in the development of pathological symptoms. When increase in weight of the seedlings is used as a criterion for comparison, the benefit derived from 5 tons of lime per acre is not so prominent.

The value of lime in tea cultivation must be considered more from its effect on soil reaction as measured on the pH scale, than from the actual quantity of lime applied to the soil, as different soils will react in differing degrees for equal additions of lime. The experiments demonstrate that for the soil used, the optimum pH value for tea seedlings lies between the pH values 5.3 and 6.5. Higher values have very detrimental effects and lead to pathological symptoms. Lower values are not so harmful.

Tea Seed:—Further complaints have been made of the poor germination of tea seed from certain estates. Investigations have shown that such seeds are healthy, but that the germination is delayed through some obscure cause, probably connected with the shell. The following figures illustrate this point.

Septobasidium:—A species of *Septobasidium* similar, if not identical with *S. bogoriense*, termed the "Grey fungus of the dadap" in the Dutch East Indies, has been found on the dadap in Ceylon. Although this species is known to penetrate and injure the cortex, the Ceylon specimens showed little penetration. The members of this genus are primarily entomogenous fungi and in this respect are beneficial. Though the fungus is unsightly on the stems, it does not appear to cause any serious damage in Ceylon.

MISCELLANEOUS.

Pestalozzia lupini has been found to cause a leaf disease of lupins, both in nurseries and when interplanted with tea. This disease, should it become prevalent, would militate against the extended use of lupin as green manure.

Neocosmospora vasinfecta has been found associated with a wilt disease of *Tephrosia candida*.

Armillaria fuscipes, already referred to as a root disease of tea, has been found on the roots of Hibiscus, growing as a hedge round a superintendent's garden.

A species of *Fusicladium* was associated with a defoliation of old Albizzias in the Bogawantalawa districts, and a species of *Phoma* with a seedlings disease of Albizzia.

C. H. GADD,
Mycologist.

REPORT OF THE AGRICULTURAL CHEMIST.

Estate Visits and Correspondence:—Since joining the Institute, 14 estates have been visited; 109 letters have been received, and 105 despatched.

SOILS.

The year's work has been entirely devoted to preliminary investigations of soil properties in order to gain familiarity with tea soils, which will allow of their orientation with respect to other tropical soils on the one hand, and temperate ones on the other.

In so doing, future work has been kept in view, but until a more thorough knowledge of general properties is obtained, from a wide selection of good and bad tea soils specific problems must perforce take second place. The examples of soils characteristics to be quoted later are given, not as generalisations, but as tendencies to which further work must be devoted before they become proved conclusions.

Physical properties:—The physical properties of a soil are of the utmost importance, for upon them the moisture relationships and cultivation operations depend. It is generally recognised that the two most important characters in determining the condition of a soil as a medium for plant growth are its organic matter content, and the quantity and kind of inorganic colloids present in the finer fractions. Both of these have been studied, but prior to resolving a soil by mechanical analysis, into its various fractions, an attempt has been made to measure the effect of organic matter and other colloidal material on the agricultural properties of the soil as a whole. Mechanical analysis is not easy of interpretation, and it would be erroneous to use generalisations based upon examination of temperate soils in explanation of tropical ones; hence the necessity for this survey.

The soil as a whole, has in each case been studied from the point of view of its organic matter content, its loss on ignition and its plastic properties. In the first instance, colloidal material is being directly measured, in the second it is being indirectly measured, and in the third, its effect on the behaviour of the soil is displayed.

Any attempt to estimate organic matter in Ceylon tea soils immediately shows how poorly stocked they are. A typical range of values is given in Table I. On all these soils attempts are being made to maintain the supply, apparently, with varying success.

TABLE I.

Percentage of Organic Matter and Loss on Ignition.

Estate	Soil horizon	Loss on Ignition	Organic matter	Combined Water.
A. N'Eliya Soil	1st	24.70	7.12	17.58
	2nd	7.30	0.60	6.70
	3rd	13.83	0.08	13.75
B. Liberal green manuring.	1st	13.40	3.67	9.73
C. Green manured but reserve still small	1st	7.21	1.71	5.50

The Nuwara Eliya type of soil is well supplied with organic matter in its first horizon, but, if by reason of erosion or other waste of top soil, the first layer is dissipated, the subsoil is deficient in the extreme. Soil C is a fair average of those examined, showing a poor reserve whilst soil B exhibits an improvement which is, in all probability, due to the liberal green manuring.

Turning to the remaining data, some indication of the inorganic colloid content can be gained from the value for combined water. This represents that portion of the loss on ignition not due to the organic matter. In the case of soils heavily charged with organic matter, the value is exaggerated, if it is taken as a measure of inorganic colloids, by the amount of combined water in association with the organic matter.

In comparison with many figures quoted in the literature of tropical soils these value are low. Soils usually designated as laterites may have as much as 25 per cent. combined water (4). These soils, therefore, are in marked distinction to such examples. The reason would appear to lie in the type of rock from which many tea soils are derived. The gneissic rock, so commonly found underlying the soil horizons, does not produce on weathering such a large proportion of water containing products as do the basalts for example. Gneiss contains large quantities of quartz which weathers to a non-water containing product. The combined water of tropical soil is associated with hydrated iron oxide, alumina, and kaolin. Briefly the colloidal properties of these soils are modified by the comparatively large admixture of non-colloidal material.

Further differences between the so-called typical laterites and the soil under examination are revealed by a study of the moisture relationships of the soil.

Those chosen for determination were :—

1. Moisture content at the lower plastic limit, *i.e.*, when the soil is just capable of being moulded. (Moulding point)
2. Moisture content at the upper plastic limit, *i.e.*, when the soil become sticky and adheres to a smooth flat surface drawn across it. (Sticky point)
3. Moisture content when the soil water mass will not retain the indentations of a spatula. (Running point).

TABLE II.

Percentage moisture contents of soils in varying states.

Estate	Horizon	Moulding Point	Sticky Point	Running Point.	Sticky point minus Moulding point
A	1st	23·8	43·2	51·7	19·4
	2nd	23·8	27·8	43·3	4·0
	3rd	40·2	47·4	83·2	7·2
C	1st	28·5	34·0	49·0	5·5
D	1st	29·4	36·9	52·3	7·5

In Table II some of these constants are set out. The first point of note is that the running point exceeds the sticky point. This is the case in all the soils so far examined. This fact distinguishes them from nearly all the soils described by Deuss, in his paper on Java tea soils, where the opposite relationship holds (1). The significance of the relative values of these constants is twofold. If a soil becomes sticky before it runs, there is some check to the erosive action of an increasing water content up to a certain point. On the other hand, soils with a low sticky point have a very narrow range of moisture content at which they are cultivable, as measured by the zone between the moulding and sticky points.

The first horizon of soil A, well supplied with organic matter as it is, shows a reasonable cultivation range. In each of the other cases it is low. Even in the top soil of C and D, the plasticity range approximates to that of a sub-soil such as A2. This unfortunately is what many of the now surface soils really are, categorically.

From the point of view of physical properties, the tea soils considered show how the colloidal properties of the soil exert a most marked effect upon their general behaviour, and how to some extent their behaviour differs from the laterite types of other countries. The colloidal fraction itself should repay detailed study.

Soil Reaction:—Tea is traditionally regarded as a crop which prefers an acid medium in which to grow. Little or no attention, however, has been given to the determination of the reaction values of Ceylon tea soils, and only one set of experiments in the field appears to have been made. These experiments, inaugurated by the Department of Agriculture give inconclusive results (Vide *The Tea Quarterly*, Vol. II, part 1).

Most crops are capable of growing vigorously over a considerable range of reaction. The results obtained so far show that tea is no exception, when all the results are collected together. On any individual soil the range is probably much more restricted, and may not by any means be identical for soils of differing characteristics.

TABLE III.
Reaction values of Tea Soils.
pH.

Soil	Horizon	pH.		Change in pH due to 1000 lb. lime.
		Good Soil	Bad Soil	
A	1	6·1	—	0·15
	2	6·1	—	0·90
	3	6·3	—	0·75
B	1	6·35	—	0·55
BB	1	5·8	—	0·40
C	1	7·0	*8·0	—
	2	6·75	*8·1	—
CC	1	6·4	*7·5	—
	2	6·4	*7·3	—
D	1	—	7·1	—
E	1	6·8	*8·25	—
	2	7·3	*8·0	—
F	1	4·5	—	—

In Table III the reaction values expressed in terms of the pH scale are given for series of soils. The determinations were made electrometrically by means of the quinhydrone electrode. It was found advantageous to use gold electrode plates.

Inspection of the Table shows that, considering only the first horizon of the soil, the values for good tea soils vary from pH 4·5 to pH 7·0, *i.e.*, from very great acidity to a value which is theoretically that of neutrality. The value 4·5 is more acid than most cultivated crops will tolerate, whilst remaining healthy. The range, taking all the values together, is a wide one. There are very distinct differences even on the same estates (vide B and BB, and C and CC). In marked contrast too, are the values for F and B, two adjoining estates. The bad soils are all on the alkaline side, providing an upper limit to the reaction of good tea soils. As between one soil and another, however, the range of good and bad would appear to overlap (*cf.* C1, pH 7·0 good, and D1, pH 7·1 bad). It is further of interest that the bad soils marked with an asterisk, were all old sites of cooly lines or gardens. The good samples corresponding to them were all taken in the very near vicinity.

Considering the variation in pH value exhibited by good tea soils, the effect of lime on these soils will obviously vary. This provides a clue to a certain amount of conflicting experience with the use of lime. Another is given by the fact that even if lime were added to a number of soils of the same pH value, its effect would be shown in different ways by different soils. This is shown by the varying value, given in the last column of Table III, for the change in acidity induced by 1000 lb. of lime. These figures are based on laboratory tests, not on field samples.

The "buffering" *i.e.*, resistance to change on adding acid or alkaline substances, varies from soil to soil, and it is noticeable that soil A1. with its superior supply of organic matter changes least. Sufficient has been said to show that the question of acidity and liming in tea is more complicated than it appears on the surface.

Exchangeable Soil Bases:—The colloidal portions of the soil have been mentioned as playing an important part in the physical condition of the soil. They play a no less important part in the realm of reaction relationships.

The colloid complex behaves as a weak acid or acidoid, with which the soil bases combine. All cultivable soils are unsaturated with respect to bases, *i.e.*, the hydrogen ions of the acidoid are not completely replaced by basic ions. Since the concentration of hydrogen ions remaining measures the acidity of the soil, the study of the soil bases and degree of saturation of the soil is seen to have important relationships with the acidity problem. Further, a study of the acidoid complex as a receptacle for basic ions offers another avenue of approach to the differentiation of soils with respect to the colloid content.

Work on these lines is not in a sufficiently advanced stage for discussion here, other than to mention that analyses show the values for absorbed bases to be low, as would be expected under the prevailing climatic conditions. The quantity of bases which would be absorbed on complete saturation is also low, reflecting again a fairly low colloid content. Finally, the relationship between degree of saturation and pH value, found by many workers on temperate soils, is demonstrated by these samples also.

FIELD EXPERIMENTS.

The final test of soil productivity and the success of cultural treatments must always be made in the field. Consequently, hand in hand with the laboratory investigations, the provision of field experiments should be undertaken. Experience shows that the best results are obtained only when these two avenues of approach to a problem are subordinated one to the other. The writer of this report has stressed, in brief articles in *The Tea Quarterly*, the necessity that the field side of an investigation should be conceived and worked out with as great a care as is usually displayed in laboratory work, and that the fundamental basis of the work should be sound.

A survey of the literature dealing with tea field experiments in Ceylon, India, and Java, shows that little attention has been paid to the fundamental questions of technique. Experiments have been laid out without any assurance that the design was adequate to the needs of the problem, or that the accuracy of experimentation was great enough to distinguish between differences caused by treatments applied, and those due to the many variable factors which should be strictly controlled even when they cannot be entirely eliminated.

Before a comprehensive series of experiments could be contemplated, it seemed, therefore, eminently advisable to determine precisely the best methods of procedure for tea, and to commence this work immediately, so that when an experimental estate should become available, some at least of the ground work should be complete. In the main, the problem to be tackled was that of studying the variability of yields due to (a) the individuality of the tea bush, (b) the heterogeneity of the land upon which

experiments have to be laid down, and (c) the errors which are introduced in the actual management of the experiment. All these factors are capable of expression quantitatively. When studied statistically, the data collected on these three points not only show how large a total error is being encountered, but that it may be analysed into a number of groups. Consequently, knowing what are the chief causes of error, and how great a contribution each cause makes, steps can be taken to reduce that contribution to its lowest possible value. The present is a most suitable time for such fundamental problems to be settled, because not only does it prevent disappointment with results of costly experiments later, but because recent marked advances which have been made in experimental methods could be tried out on tea.

Scrubs Uniformity Trial:—The method of procedure has been to set up a Uniformity Trial on an area of two acres, which The Ceylon Tea Plantations Co. loaned to the Institute for that purpose. A diagrammatic representation of the trial is shown in the accompanying figure.

The area included in the experiment is a piece of high yielding tea without cover which is cultivated on a three year pruning cycle. It is a matter for regret that it was not possible to commence the experiment immediately after pruning, but no suitable piece of ground carrying newly pruned tea was available when the writer joined the staff of the Institute. Rather than let any time elapse before starting this necessary investigation, the experiment was commenced on tea which was 16 months out of pruning. We believe that the results obtained over the remaining twenty months will provide a satisfactory basis for establishing the points upon which information is desired. The field is subject to the ordinary routine operations of estate practice in cultivation and manuring. As will be seen from the two topographical sections, it comprises a steep but uniform slope, roughly North and South, and fears that it will be unrepresentative of the type of land ordinary encountered in estate practice, should be consequently minimised.

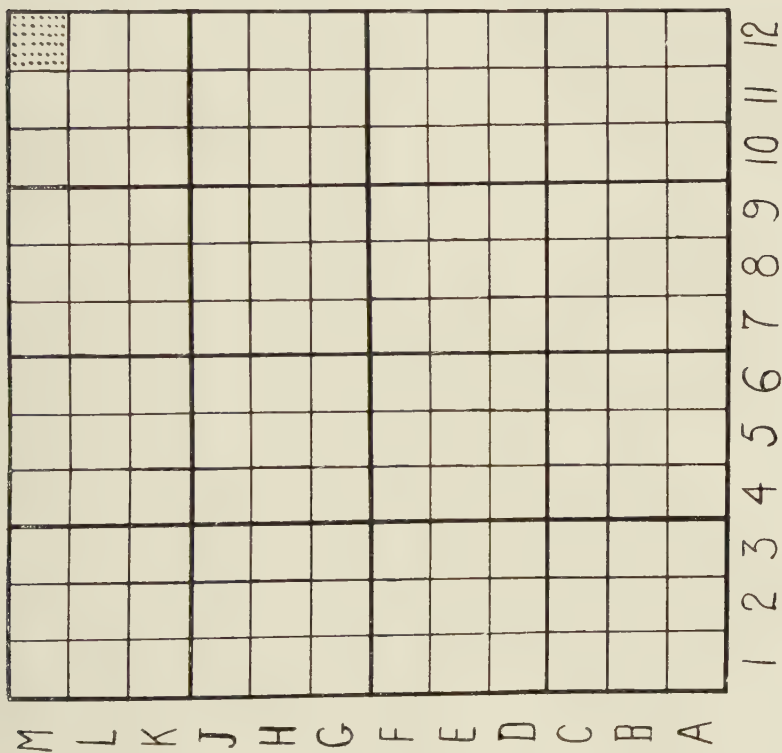
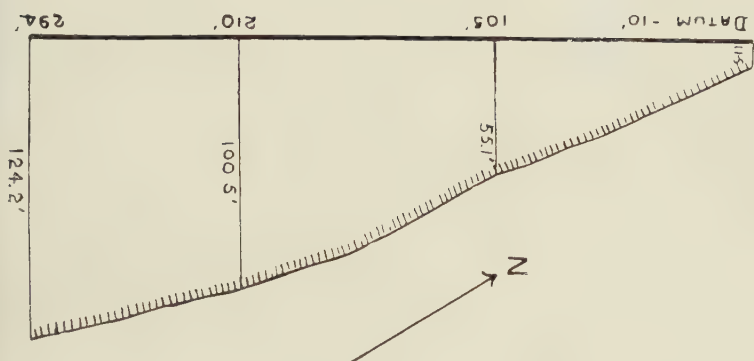
The area was divided into 144 small plots, each plot containing 6 rows and approximately seven bushes per row. That the number of bushes per row is not uniform is due to the division of the ground upon an area basis, instead of a bush basis, for reasons which will appear later.

Each plot was surveyed, and its boundary marked by a fencing of stout wire carried on permanent iron corner posts. Where such plot boundaries cut across a bush, the plucking is carried up to the wire in respect of each plot.

During the calendar year under report, nineteen pluckings have been made commencing on April 20th. These have been personally superintended, and all weighing and sampling operations personally made. Only in this way could the absolute reliability of the results be ensured. The data from which tentative conclusions will later be deduced refer only to the first twelve plucking rounds. The dates of plucking have been those which would normally have occurred on the field in question, and they vary from 10 to 18 days. Each plot is provided with a numbered basket into which the pluck is collected so that complete identification is assured.

Management and Expression of Yields:—One of the first points to be decided was one of management. The initial attempt of having 12 pluckers has been entirely successful. These are distributed one in each plot along

UNIFORMITY TRIAL
THE SCRUBS ESTATE.



Row A, and upon completion of a plot, the plucker moves on to the corresponding plot of Row B, and so on up to the major incline. With a very few unavoidable exceptions, the same team of pluckers is employed at each round, and they are disposed of over the same plot series on each occasion *i.e.*, the first plot in each row A to M is plucked each round by the same individual.

A second important point of management is the method employed in expression of yields and in ensuring their comparability. The frequent advent of rain during plucking naturally exaggerates apparent yields. If this were not taken into account, it would destroy the comparability of plots and increase substantially the error of an experiment. Even where no rain falls, the apparent yield of plots varies owing to dew deposits and the change in weight of leaf due to transpiration losses over the course of a day's plucking. It is unsatisfactory to rely upon an empirical correction to counterbalance these two disturbing factors, and consequently, the absolute dry matter of the leaf has been taken as the basis of all comparisons. This ensures that no matter what the weather conditions are during the course of one plucking, or from round to round, all figures are strictly comparable. The plots of each lettered row of the trial are, within narrow limits, plucked simultaneously. Samples of each plot yield are taken immediately after weighing, and bulked. From the bulked sample of the whole row of 12 plots, quadruplicate representative samples are taken in air-tight tins. The fresh weight and the weight after drying at the temperature of boiling water, of these samples, afford an adequate basis for the calculation of the dry weight of the whole row.

The variability in the ratio Fresh weight/Dry weight on three typical occasions is shown in Table IV.

TABLE IV.

Fresh Weight/Dry Weight of Green Leaf.

	Row	A	B	C	D	E	F	G	H	J	K	L	M
Date	Apr. 30	4.30	4.30	4.22	4.20	4.08	4.01	4.01	4.24	4.36	4.38	5.51	5.59
	Sep. 3	5.0	5.18	5.10	5.21	5.15	5.06	5.23	5.14	5.24	5.09	4.70	4.62
	Sep. 18	4.08	4.08	4.04	3.97	3.98	4.01	4.00	3.94	3.94	3.78	3.85	3.79

The first example shows the progress of the moisture content through the dew stage with gradual drying off and probably some transpiration loss, culminating in an increasing ratio due to gentle and finally heavy rain. The second example is taken from a typical day of continuous rain with some slackening at the end. The third case is from a plucking round when no rain fell, where all fluctuation is due to transpiration controlled by the amount of insolation experienced at different times of the day. The difference between F or G and M (April 30) represents the presence of over 50 per cent. more moisture, or in terms of apparent increase in weight of the crop, nearly 16 per cent.

It is of interest that the driest leaf was plucked during the slowest growing period of the S. W. monsoon, the average FW/DW ratio of the whole pluck being 3.93. It is evident that the reduction of yields to dry weight will have to be routine operation in all future experiments.

Influence of Design on Error—Plot size. The yield data of the uniformity trial can be used in order to determine (1) the best size of plot to use, (2) the number of plots which must be assigned to each treatment (including so called "control" plots) in order to obtain sufficiently accurate results, (3) the best arrangement of plots to ensure low and valid estimate of error. The best size of plot can be investigated by supposing that the area under consideration is an actual experiment, composed of a series of plots of various sizes. It was with a view to developing this aspect that the field was divided into a large number of small plots, which could be amalgamated in groups to build up plots of varying sizes. With small plots as units, a larger variety of shapes and sizes can be formed than with large plots. This is the justification for starting out with such diminutive specimens. As will be seen later, the unit plot is much too small for accuracy and practical convenience.

Up to the present, the design investigated has been confined to the Latin Square, a form which has met with much practical success in field trials with other crops. A description of this design with a summary of its advantages has been given elsewhere. (2,3.)

The plot sizes employed have been units of one, four and nine plots, *i.e.*, amalgamating A1, A2, B1, B2, and so on, and similarly A1, 2, 3, B1, 2, 3, C1, 2, 3, for the nine plot unit. Full details of method will be published subsequently, but for purposes this report an example from one plucking is given of the reduction in error consequent on employing larger plots.

Plot size in units	...	...	1	4	9
Standard error % of one plot	...	...	20.7	11.8	6.6
Theoretical S. E.	...	...		10.35	6.9

When plotted out in graphic form, as error against size, it will be seen that although the error is diminished as plot size increases, it is not diminished proportionally, and that by the time a nine plot unit is reached, the curve of error has become very much flattened out. Consequently, increase in plot size will affect the error only to a degree too small to compensate for the larger area occupied. It should be remembered that errors can also be reduced by increasing the replication of plots. When the error by means of increased plot size ceases to diminish rapidly, it is more advantageous to stabilize the plot size at that value, and reduce error by having recourse to replications to the full extent of the land available, rather than to cut down replications for the sake of a lesser advantage obtained by large plots.

A further point of note is that the actual experimental value of the standard error, as determined in this experiment, follows closely the random error expected on theoretical grounds. One may, therefore, calculate how much further the error would be diminished had larger plots been tried, a procedure which was experimentally impossible on account of the limit of the land available. For 16 plots, the value obtained theoretically in this case would have been 5.2 per cent., a small decrease (1.7 per cent.) considering that nearly double the land would have been required. This example represents accurately the degree of error diminution accompanying the employment of varying plot sizes. Other pluckings, whilst showing a similar behaviour, gave an absolute value for the error which was higher.

Plot Design. The design of a field experiment greatly affects both the accuracy of the trial and the amount of information that can be obtained from it. The efficiency of the Latin square formation has been tested on the data provided by the Uniformity Trial. Table V is a concrete example of one of the 576, 4 x 4 Latin Squares which could be made up from the nine unit plots. The letters assigned to each plot refer to hypothetical treatments. In this way it is possible to see how such an area would behave, if an actual experiment involving four treatments were carried out on it.

TABLE V.
Yield of Plots in 4 x 4 Latin Squares

	C	A	B	D	Row Totals
	228.8	251.2	214.3	199.2	893.5
A		C	D	B	
246.1	263.6	240.7	264.5	1014.9	
D		B	A	C	
263.8	279.7	272.3	278.1	1093.9	
B		D	C	A	
218.9	247.3	214.1	284.6	964.9	
Column Totals.	957.6	1041.8	941.4	1026.4	
Treatment Totals.	A	1054.2			
	B	977.4			
	C	984.6			
	D	951.0			

The first point of note is that although the four treatments are identical, the total yields for each treatment are unequal. This is the natural consequence of the fact that the fertility of the plots is not uniform, and that errors of one sort and another are encountered.

Secondly, remembering that each row contains each treatment, the variation in the row totals shows that an apparent yield gradient exists from top to bottom of the experiment, and that this yield gradient is independent of plot treatment.

Exactly the same reasoning holds for the column totals, and a good deal of interest centres round these two sets of values. The variation in row totals can be ascribed to soil heterogeneity and bush variation. The variation in column totals is due to the same causes plus the further disturbing factor of the individuality of the plucker. Each row total is the product of the plucking of the same coolies; each column total is the product of different groups of coolies.

The actual variation in yield due to these three causes has been evaluated in statistical terms, together with the remaining random variation to which it is not possible to assign a cause. Table VI gives these values.

TABLE VI.
Variance of Yield due to several causes.

Treatment	...	...	484
Rows	...	...	1778
Columns	...	...	617
Remainder	...	...	319

The value of the remainder variance is the one which determines ultimately the error of the experiment, and it can accordingly be used as the standard of comparison. The treatment value is of the same order as that for the remainder and statistical tests show no significant difference. Hence it follows that the effect of treatment is nil. Since the treatments in this case were identical, this is as it should be and shows that the design is a sound one. The greatest value is for Rows, *i.e.*, the influence of soil variation down the slope. It is greater than that for columns, and the existence of a definite fertility gradient down the slope is a statistical probability. The column variance is of the same order as the remainder, and thus cannot be judged significant. Since it includes variation due to the individuality of the plucker, this shows that no systematic variation of importance exists in the hardness of plucking by different groups of pluckers. In an experiment carried on over a long period this point is of importance.

The value of determining the magnitude of these variations is not merely a matter of interest. Those for rows and columns do not affect the differences between treatments, and can be eliminated. Had they not been determined they would have gone to swell the value for the remainder, and consequently the error of the experiment. The actual error of one plot, of the mean of four plots, which is what the experiment allows, and the standard error of the difference between two means are given in Table VII for the 12 occasions.

TABLE VII.

	Standard Error per cent.											
Plucking	1	2	3	4	5	6	7	8	9	10	11	12
S. E. one plot	6.6	9.3	9.9	7.2	13.2	10.8	9.3	12.3	10.2	10.9	14.3	14.9
S. E. mean of four	3.3	4.7	4.9	3.6	6.6	5.4	4.6	6.2	5.1	5.5	7.2	7.5
S. E. difference of means	4.6	6.6	7.0	5.1	9.4	7.6	6.6	8.7	7.2	7.7	10.1	10.5

It will be seen that the residual error, when all precautions have been taken, is both large and variable. Generally speaking the errors have increased as the crop fell, and as most of these dozen plucking rounds have coincided with low cropping, it is hoped that the higher figures represent a maximum. By doubling the figures for S. E. of differences of means, an approximate value is obtained for the magnitude of differences which in any experiment of this type could be called significant and certain. These values range from 10–20 per cent. and are too great for the accuracy aimed at. Since it has been shown that no marked advantage will arise by increasing plot size, the indications point to increased replications as the proper course to take. Quadruplicates are evidently too few; six replications at least should be tried.

Replication in Time.—A further possibility presents itself as a method of reducing the error still further. If we can regard each plucking as a representative expression of the yield of the various parts of the experiment throughout the pruning cycle, we shall have not one experiment but as many as there are pluckings. It would only be possible if for consecutive pluckings, the correlation between plot yields was high and positive. Examination has shown that it is positive but not high. Consequently, one plucking is likely to be insufficient to represent the comparative yield of a plot. It is however worth while determining how many pluckings do give a representative yield, and then by dividing up the pluckings into units of that number, obtaining a series of replications in time, just as we have replications in space in the field,

Accordingly, the plot yields have been grouped into lots of 1, 3, 6 and 12 pluckings and the errors calculated on that basis.

The standard error of the mean of comparable plots according to the various groupings are as follows :—

	All together	In sixes	In threes	Singly
S.E.	4.01%	3.14%	2.40%	1.61%

It will be seen that the correlation between successive pluckings is after all sufficiently high for the increased replication due to grouping to have effect in giving a substantial reduction in error. Whilst over a whole pruning cycle it would not be expedient to deal with individual pluckings, there is every indication that some such system of grouping can be used to reduce errors to a reasonable standard of accuracy.

Conclusions.—The yields of a Uniformity Trial have been examined over a period of twelve pluckings. The information obtained has been used with a view to exploring fruitful methods of treating the whole body of data when this becomes available. The indications given by the short period trial are as follows :—

(I) It is essential in order to ensure accuracy that weights of green leaf plucked and weighed on the field should be reduced to dry weight in order to compensate for the vagaries of the climate.

(II) The Latin square design interpreted by statistical methods offers a useful means of reducing the errors of yield trials and of accurately determining their values.

(III) This design further eliminates a considerable proportion of the contribution to experimental error made by soil fertility slopes and variation in hardness of plucking.

(IV) By investigating plot size in relationship to error, it appears that a nine unit plot (approximately $1/8$ acre in area) is a convenient size and that by increasing the size, the representativeness of plots will not be enhanced, *i.e.*, the error will not be further reduced, to worth while degree.

(V) Four replications of each treatment are insufficient to ensure the accuracy desired. Six is suggested as a minimum.

(VI) The attempt to group yields with a view to obtaining replications in both space and time, gives a marked improvement in the accuracy of the experiment.

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T. EDEN,
Agricultural Chemist,

REPORT OF THE BIOCHEMIST

Advisory:—94 letters have been received, and 93 have been sent out. The number of letters asking for information on technological questions is increasing, and indicates a healthy and growing interest in technical innovations pertaining to the process of tea manufacture. Visits were paid during the year to the following estates:—Rickarton, Panawatte, Blairlmond, Middleton and Spring Valley.

Research:—The installation of the gas plant and the appointment, in June, of a chemical assistant have made it possible to carry out a systematic investigation of certain problems during the year. The main themes have been the seasonal changes in the chemical composition of fresh leaf and made tea, and the transformations in withering leaf.

THE SEASONAL VARIATION IN FRESH LEAF.

The quality of made tea will depend on the composition of the fresh leaf which enters the factory after each pluck. Any investigation of quality must, in the first instance, concern itself with the quantitative determination of the variation in the composition of the fresh leaf, and, if possible, correlate the variations of the constituents found with each other, with time from pruning, with growth rate as measured by crop production, and with the meteorological data available. This work was started in 1927 and referred to in the Report for that year, but it has been possible during the year under consideration to extend the scope of the work by linking up the investigation with that carried out by the Agricultural Chemist on plot variation. The samples obtained for analysis were taken from the field plots described in the Agricultural Chemist's Report. The plucking and sampling were carried out under controlled conditions so as to reduce the sampling errors to a minimum. Each pluck is represented by four mixed samples, which are dried and then analysed for total solids soluble in water, tannin, gummy material, and nitrogen in the extract as well as total nitrogen in the dry leaf.

The study of the water soluble material has been carried out in aqueous extracts, prepared by boiling 5 gms. of leaf with 400 c.c. of water for 45 minutes, allowing this to cool, and filtering after making the whole up to 500 c.c. with distilled water. A difficulty in the estimation of tannin by the formaldehyde method was encountered during this work, as the precipitation of the tannin-formaldehyde compound was interfered with by the presence of some substance or substances in the leaf at certain times. When the acid and formalin were added to the water extract, a suspension was formed which did not coagulate on warming until a few drops of alcohol were added. The precipitate then obtained was, however, too gelatinous to be filtered freely.

The method of preparing the tannin-formaldehyde compound was consequently investigated. Since this compound is normally coagulated on warming and the addition of alcohol helped the precipitation in the present instance it would appear that precipitation was prevented by the presence of some substances which were put out of action by the alcohol. When alcohol is added to the water extract of dried leaf, a gelatinous precipitate is obtained, and the tannin can be easily precipitated in the filtrate obtained when most of the alcohol has been removed. If this gelatinous precipitate is not removed before estimating tannin by precipitation, it is removed along with the tannin and weighed as such, thus introducing an error into the

estimation of tannin. The presence of small quantities of alcohol, when precipitating the tannin, also prevents some of the colouring matter in solution from being included in the precipitate.

In view of this, the method of estimating tannin was modified, and the following method of analysis was finally evolved. 50 c.c. of the water extract are evaporated to dryness, which gives the total amount of solids in the extract. 200 c.c. of the extract are evaporated to dryness under reduced pressure; the dry matter is dissolved in 25 c.c. of 10 per cent. alcohol and the whole made up to 100 c.c. with rectified spirits of wine. The gummy material is thus precipitated, and the solution filtered. Aliquot portions are then taken to determine the tannin and the total solids remaining in solution in alcohol.

A closer control of plucking coupled with this method of analysis has brought the following interesting facts concerning the variation in the composition of the pluck to light.

The soluble material of the leaf increases during the day, this increase being represented chiefly by a greater amount of the gummy materials which are precipitated by alcohol, as will be seen from Table I.

TABLE I.
Periodical Change in the Composition of the Pluck during the day.

	Morning pluck		Evening pluck	
	1st Period	2nd Period	3rd Period	4th Period
Total Extract	36.4	42.7	46.1	46.9
Precipitated by Alcohol.	0.0	2.4	4.0	6.7
Total Tannin	17.7	19.0	20.4	20.4

It is not surprising to find an increase in the water soluble material of the leaf during the day when it is remembered that the leaf is an assimilating organ; but the question arises whether this hourly variation in the composition of the leaf affects the quality of the tea produced. Such effect would be expected from the analyses, but there does not appear to be any practical experience to confirm this, as any change that may occur during the day would be masked by bulking the day's break.

The increase in water soluble material is more marked during fine weather, especially if a fine day is experienced for plucking; while leaf plucked during a period of very wet weather may not show this variation at all. Thus, during the monsoon period, when wet and cloudy weather existed for several weeks, the plucked leaf varied irregularly during the day, but a change to fine weather and clear skies resulted in the same regular increase in the constituents of the leaf.

The effect of climatic conditions appear to be cumulative. Although the soluble constituents of the leaf show a temporary increase during a short period of fine weather met with during the South-West monsoon, the tendency is for the water soluble material to decrease from pluck to pluck during the wet weather. This tendency to decrease is very marked in the case of the total nitrogen of the leaf, nitrogen in the extract, and also in the non-tannin portion of the extract. The total tannin on the other hand shows a big variation from pluck to pluck, but the tendency, seen in other constituents to become uniformly less, is not shown by the figures for this substance.

TABLE II.

Effect of Climatic Conditions on the Composition of Tea Leaf.

Date of pluck.		Extract	Tannin	Non-Tannin	Nitrogen in Extract.
20-4-28	Period of rapid growth	44.8	18.5	26.3	1.89
30-4-28	before monsoon.	44.2	18.4	25.3	1.79
3-9-28	A spell of fine weather	40.20	19.07	21.2	1.50
18-9-28	during the monsoon.	41.31	18.95	22.3	1.51
	2.03 in. of rain in 12 out of 30 days.				
3-10-28	Continuous rain. 10.9 in.	36.82	15.56	21.26	1.46
17-10-28	of rain in 25 out of 30 days.	35.30	15.20	20.10	1.38

The last two plucks constitute leaf which has grown during a period of continuous rain, and the amount of solids in the extract has reached a lower figure than previously met with. This drop in the solid constituents of the extract is also accompanied by a fall in the tannin content. The figures for the September plucks illustrate the drop in the amount of solids in the extract, non-tannins, and nitrogen in the extract as a result of continued wet weather, in spite of the fact that a short spell of fine weather was experienced at the beginning of September, when this leaf was plucked. These figures are, however, slightly higher than those found for the immediately preceeding plucks, which are not shown in the table. Close inspection shows that the tannin content does not exhibit the same regular variation as the other constituents.

The total nitrogen of the leaf diminishes in a similar manner to the nitrogen in the extract. Apparently, the utilisation of nitrogen by the bush is not always the same. This may be of great importance when manurial treatment is considered, *e.g.*, at what time to apply a nitrogenous manure.

THE SEASONAL VARIATION IN THE COMPOSITION OF MADE TEA.

The study of the seasonal change in the composition of fresh tea leaf has been supplemented by analyses of made tea from certain districts in the Island. For this investigation samples of made tea, accompanied by their valuations and taster's remarks, are sent in for analysis once a month from one estate in each of the following districts:—Badulla, Dimbula, Uda Pussellawa, Maskeliya, Haputale, and Neboda.

Correlation between the chemical composition of made teas and their qualities has been the subject of several investigations, but it must be admitted that the results have been disappointing. Most of the workers had in view the idea of tracing the quality of tea to one particular component, and samples of teas from different estates were taken for analysis.

It is not surprising that this method of investigation led to very conflicting results when it is remembered that teas are manufactured for different tastes and markets. Experience shows that it is better, on some estates, to aim at strength in the liquors than to attempt to turn out flavoury teas. The method of manufacture is varied accordingly, and this must be taken into consideration when comparing the chemical composition of the two types of tea.

The seasonal differences in the quality of the tea made on any one estate is very marked, and provided the mode of manufacture is not appreciably altered, there is no reason why a chemical investigation should not throw light on the factors which determine the quality of tea. It must be borne in mind, however, that a chemical assay does not take account of the appearance of made tea or of the presence of taints, both of which are considered when a tea is valued. Also the market demand fluctuates so much that a very close parallel between the result of chemical analysis and the ordinary valuation is not to be expected.

In the past most attention has been given to the tannin complex of tea. Although this may appear to be the main factor in deciding the astringency of a cup of tea, it does not necessarily follow that the most astringent tea contains most tannin, since the astringency will be greatly modified by the presence of other substances which have not yet been so closely investigated. The actual taste observed is the result of several inter-dependent factors; when considering quality in tea it must be borne in mind that a cup of tea contains other substances besides tannin, and that these also vary according to the climatic and other conditions.

It is a well known fact that a good tea can be spoilt by careless infusion, so it is necessary to adhere strictly to one adopted method in order to obtain uniformity in the liquors for analysis. Any deviation from the usual procedure results in a different liquor as the nature of the brew depends on the substances extracted and their relative proportions. If these substances are extracted at different rates, then a slight difference in method of brewing will produce a different liquor, and the number of variations possible is very great.

The rate at which the different constituents of tea are extracted have been determined as a preliminary to the work on made tea, and the results are given in Table III.

TABLE III.
Rate of Extraction of Soluble Material from Tea.

Time of infusion in minutes.	Soluble Extract.	Tannin.	Acid Soluble Tannin.	Tannin precipitated by acid.	Nitrogen in Extract	Other Substances.
1	18·9	5·8	4·5	1·3	1·19	13·1
2	26·6	9·3	7·3	2·0	1·56	17·3
3	31·2	11·3	8·9	2·4	1·68	19·9
4	32·7	12·9	10·5	2·5	1·82	19·8
5	33·4	13·8	10·0	3·8	1·79	19·6
6	34·9	15·1	11·4	3·7	—	19·8
8	35·6	15·6	12·1	3·5	1·88	20·0
10	37·7	17·5	13·1	4·5	1·93	20·2

It will be seen that the non-tannin substances are the most easily extracted substances in the leaf, being almost completely extracted after 5 minutes contact with boiling water. These non-tannin substances include the caffeine, 80—90 per cent. of which is extracted during the first 4·5 minutes of infusion. A longer brew results in an increase of the quantity of tannin in solution without a corresponding increase of the other constituents.

A similar effect is produced by pouring off the first infusion and adding a fresh supply of boiling water. It is true that a further quantity of material passes into solution at the second infusion, but the concentration of

solids in this solution is much less than that of the first infusion, and the relative proportion of the various substances is quite different. This second infusion contains little caffeine, and hardly any of the ash constituents, most of which are removed in the first brew.

The custom of allowing tea to draw for five minutes ensures almost complete extraction of the non-tannin substances, including the soluble nitrogenous material, without completely extracting the tannin. This is true for the various grades of tea, although the percentage of tannin extracted in a definite time varies with the amount of tannin in the particular grade and also with the degree of fineness of the tea used. The influence of the non-tannin fraction on the taste of brewed tea has been little investigated up to the present, although it appears to be as important in this respect as the tannin. This has been kept in mind when planning the investigation of fresh leaf and made tea.

Several forms of tannin, differing in their solubility in water, undoubtedly exist in tea; some are easily extracted, while others are dissolved only with difficulty. One form of tannin is precipitated on acidifying the water extract, and, in several papers on the physiological action of tea as a beverage, it is referred to as a compound of tannin and caffeine. The tannin present in this form is considered to be physiological harmless.

Although the results of the previous workers demonstrated a variable tannin/caffeine ratio, it was maintained that the precipitate dealt with was a chemical compound. The evidence of it being a chemical compound is, however, not very conclusive, as the association of caffeine with the tannin in the precipitate may be explained as an absorption effect, the caffeine being drawn out of solution along with the tannin. The ratio tannin/caffeine would then depend on the concentration of the solution, the amount of precipitate obtained, and also on the conditions existing during the precipitation.

The precipitate obtained on acidifying a tea extract contains nitrogen, and the amount of nitrogen present is often taken as a measure of the caffeine. The ratio tannin/nitrogen has been found to vary with the concentration of the solution in a progressive manner; actual ratios found being 13, 11, 17, 25, with increasing concentration of the solution used. The ratio also varies if other conditions are changed during the precipitation. These observations are in agreement with the hypothesis that the presence of caffeine is due to surface action, and not to the formation of any definite chemical compound.

The liquors obtained from the various grades of tea show marked differences, and it is interesting to see how these differences are reflected in the chemical analysis of the grades. Comparable analyses are given in Table IV.

TABLE IV.
The Chemical Composition of Various Grades of Tea.

	B.O.P.	O.P.	Pekoe.	Dust.
Total Extract	40.50	39.0	37.2	38.75
Total Tannin	18.90	16.02	16.2	17.36
Non-Tannin Substances	21.60	22.98	21.0	21.39
Nitrogen in the Extract	1.93	1.67	1.8	1.90

Apart from the difference in the total amount of the solids extracted by water from the different grades of tea, there is also a difference in the

distribution of the substances estimated in the extract. The non-tannin substances in the Orange Pekoe appear to be distinctly higher than in the extracts obtained from the other grades and the tannin content is considerably lower. This particular grade should, therefore, give less astringent liquors than B.O.P. which is richer in tannin. It would appear from the composition of the B.O.P. that this leaf could be more strongly fermented in order to produce strength of liquor without losing too much of its astringency whereas the O.P. would lose most of its astringency if fermented too strongly. The nitrogen in the extract obtained varies a good deal, being highest in the extracts obtained from B.O.P. and lowest in the O.P. Although the analysis of the Pekoe, shown in the present table, is different from that of the B.O.P., it has been found that this difference is not always so well marked. At certain periods, especially when good teas are made, the analysis of the Pekoe grade shows a very close approximation to that of the B.O.P. Pekoes made during the wet weather, on the other hand, invariably show a marked difference from the B.O.P.

These preliminary investigations point to certain substances as being of great importance, and this has been taken into consideration in carrying out the investigation of the seasonal change in the composition of made tea. Although a considerable amount of data concerning the composition of the tea sent in has been collected, it is not possible, as yet, to give more than a cursory account of the work.

The moisture content of the teas sent in for analysis is about 6 per cent., but there is considerable variation from month to month in samples sent in from the same estate. The variation, ranging between 4·6 and 10 per cent., is probably due to differences in the humidity of the atmosphere at the time the tea is manufactured, as wet weather teas contain most moisture.

The incidence of wet weather in certain districts is clearly reflected in the teas made in those districts, and results in a smaller quantity of water soluble material in the made tea. These observations confirm those already noted from analysis of fresh leaf, including that concerning the cumulative effect of prolonged wet weather. The non-tannin substances also show a progressive decrease as the wet weather continues, in the same way as was found with the fresh leaf samples. Samples from the dry districts exhibited a steady increase in the water soluble material as the dry weather continued, the highest point being reached in all cases in the month of September, when very fine prices were obtained. When the wet weather set in, a very sudden drop in the water soluble material in the extract followed in all cases.

Although the valuations were much lower for October teas, the lower prices did not seem to be as low as would be expected from the change in the chemical composition.

That the composition of a high grown tea is different from that of low grown tea may be seen from the following Table V.

TABLE V.
Composition of Tea made at different altitudes.

		High grown.	Medium grown.	Low grown.
Total Extract	Per cent.	43·33	39·03	35·17
Total Tannin	„ „	20·86	18·29	15·30
Non-Tannin	„ „	22·47	20·70	19·87
Valuation	Rupees	1/40	1/10	-/86

The composition of fresh leaf grown at a low elevation is not very different from that grown at a higher elevation; so the big difference found in the made tea is very largely due to different conditions of manufacture—the higher temperature existing at lower elevations causing a more rapid fermentation than at higher elevations. The greater strength of liquor usually obtained from low grown teas is not due to a greater amount of substance in solution; in fact, these strong liquoring teas generally contain less soluble material than thin liquoring teas, unless the thin liquor is due to over-fermentation, when the liquors will also appear dull.

The investigation of the composition of made tea will be continued, and when sufficient data have been accumulated, they will be submitted to a statistical analysis and fully reported.

WITHERING.

The plucked shoots, which are still living when spread on the tats, carry on many of the processes which they performed when attached to the bush. Thus, the leaf actually respire during the process of withering, and experiments have demonstrated that respiration is still active in leaf withered to 55 per cent. although the rate of respiration is then less than that of fresh plucked leaf.

Normal respiration is an oxidative process, whereby the leaf takes up oxygen from the air and sets free carbon dioxide with the liberation of heat energy available to the leaf for its activities. The rate of respiration has been followed quantitatively by determining the amount of carbon dioxide produced, and by measuring the volume of oxygen absorbed in unit time. The numerical value of the ratio, carbon dioxide/oxygen taken up, is approximately *one* for most plants, and this value holds true for the tea leaf also.

TABLE VI.

Respiration of Tea Leaf

	Volume of CO ₂ produced by 40 gms. of tea leaf in one hour.	Volume of Oxygen absorbed by 40 gms. of tea leaf in one hour.	Ratio CO ₂ / O ₂
	c.c.	c.c.	
(1) Fresh Leaf	13·9	17·4	0·8
(2) Fresh Leaf crushed	14·1	17·6	0·8
(3) Leaf withered to 55%	9·8	11·0	0·9
(4) Leaf withered to 55% and then crushed.	3·4	26·0	0·13

The ratio CO₂/O₂ (see Table VI) is practically the same for fresh and withered leaf, so that there is no apparent change in the nature of the respiratory process during withering. It is interesting to note that when withered leaf is crushed, the amount of carbon dioxide evolved decreases and the oxygen uptake shows a rapid increase. This causes the ratio CO₂/O₂ to become very small. The respiratory process is, therefore, completely upset when withered leaf is crushed. Then the oxygen absorbed bears no relation to the amount of carbon dioxide evolved. This change was not observed when fresh leaf was crushed; and it has not yet been determined in what stage of the withering process the change begins.

The uptake of oxygen is very rapid for the first hour after the withered leaf is crushed, but then decreases slowly until the ratio CO_2 / O_2 again approximates to unity. The increase in oxygen uptake by injured tissue appears to be general for plants which contain tannin in their cells. It is accompanied by a change of colour, which is associated with the oxidation of tannin and glucosides by appropriate enzymes such as oxidases (Haas and Hill. *An Introduction to the Chemistry of Plant Products* Vol. II, p.80).

The evolution of carbon dioxide during the respiratory process results in a loss of dry matter from the leaf, so that a real loss of the dry matter of the leaf takes place during withering. The amount of carbon dioxide produced during withering is considerable, and it is necessary that this carbon dioxide is removed from the withering lofts. Otherwise, the accumulation of this gas in the air may have a deleterious effect on the leaf, since a high concentration of carbon dioxide in the air is liable to retard the normal oxidative process in the leaf, and to result in the production of partially oxidised substances like alcohol.

The carbon dioxide is easily removed when natural withering conditions exist, but its removal is a factor to be considered when artificial withering is resorted to. The windows are then closed, and the temperature of the loft is increased by admitting warm air which increases the rate of respiration. As ventilation during artificial withering is dependent on the draw of the fans, unless the fans have a sufficient capacity there will be an accumulation of carbon dioxide in the lofts. This danger seems to have been realised to a certain extent, for when warm air is used to take off the surface moisture from the leaf, it is customary to open the windows to admit fresh air after a time. The products of respiration are then removed by the entry of a plentiful supply of cool, fresh air. It is, however, just as necessary to ascertain that the ventilation is satisfactory over the whole area of the lofts when hot air is used, otherwise local accumulation of carbon dioxide, which is a heavy gas, takes place. The active respiration of withering leaf also explains why a supply of fresh air is necessary for the leaf on the tats, when it is remembered that normal respiration involves the uptake of oxygen.

TABLE VII.

Volume of CO_2 produced by 40 gms. rolled tea leaf at 18°C .

1st hour after rolling	...	...	4.6 c.c.
3rd " " "	...	...	4.6 c.c.
5th " " "	...	...	4.3 c.c.
7th " " "	...	...	3.8 c.c.

Carbon dioxide is also one of the products of tea "fermentation". The volume of carbon dioxide produced by fermenting leaf decreases slightly during the process, which is contrary to what would be expected if the 'fermentation' was due to the activity of micro-organisms. In the latter case, the amount of carbon dioxide produced should increase rapidly with the growth of the micro-organisms.

When a withering leaf is considered as a living entity, carrying on many of the processes it performed on the bush, it is impossible to maintain that no chemical transformations take place during the process. The problem, however, is to determine what role these changes play in preparing the leaf for the 'fermentation' induced by rolling.

It was pointed out in last year's Report that there is a slight increase in the water-soluble constituents of the leaf during withering, but when the loss of weight due to respiration is taken into account, the gain in soluble material disappears. When the nitrogen content of fresh and withered leaf is determined, a slight increase is found in the nitrogen content of withered leaf over that of the fresh leaf. The change in total nitrogen gives a measure of the material lost in respiration, and this loss has been taken into consideration when the results of the analysis of the soluble material is considered.

When the method of analysis described in this report is applied to fresh and withered leaf, certain interesting differences are found between the two.

TABLE VIII.

Composition of Fresh and Withered Tea leaf.

	Extract		Alcohol soluble	Alcohol insoluble	Tannin	Total non-tannin	Nitrogen in extract	Total nitrogen.
	Uncorrected for respiratory loss %	Corrected for respiratory loss. %						
I Fresh Leaf	38·5	38·5	35·58	2·92	14·65	23·85	1·64	4·53
Leaf withered 24 hours.	40·05	38·9	34·80	4·10	14·80	24·10	1·74	4·68
Leaf withered 48 hours.	40·34	38·8	34·60	4·20	15·00	23·70	1·83	4·73
II Fresh Leaf	39·46	39·46	36·22	3·24	14·95	24·51	1·64	4·42
Withered 2 days	41·62	40·05	35·33	4·70	15·20	25·40	1·74	4·51
Withered 3 days	40·82	39·60	35·00	4·60	14·80	24·80	1·81	4·55

It will be seen from Table VIII that:—

(1) Although the water soluble material has increased when reckoned on the amount of leaf used, the difference has disappeared when the dry matter lost in respiration is taken into account.

(2) There is a difference in the distribution of the various constituents in fresh and withered leaf. The material soluble in alcohol has diminished during withering in the two samples shown, while the gummy material insoluble in alcohol has increased by 38 and 45 per cent. The tannin has also increased, though it would appear from these results that, when the wither is prolonged, there is a tendency for the tannin to diminish.

(3) The nitrogen extracted increases during the wither. This is probably due to the hydrolysis of protein substances of the leaf with the formation of amino acids and other less complicated bodies. The presence of soluble nitrogenous compounds, other than caffeine, in an extract of tea is shown by the fact that the soluble nitrogen is greater than will account for the caffeine present. The rate at which the soluble nitrogen increases under Nuwara Eliya conditions would be increased in a warmer climate. In view of this, it is not surprising that too long a wither is to be avoided where withering temperatures are high, as degradation of protein substance is liable to sour the leaf and produce objectionably odoured substances.

If these decompositions are necessary to prepare the leaf for the fermentation, the withering process becomes very complicated, and the loss of moisture is certainly not the only question worthy of consideration. The length of the withering period will depend not only on the temperature, but also on the climatic conditions governing the growth of the leaf, as it is possible that the rate of withering will vary with the quantity of materials stored in the leaf as a result of assimilatory activities. If so, no rigid time limit would be possible for withering on any estate, as the time required for a proper wither would vary from season to season. This probably accounts for the diversity of opinions expressed regarding an optimum withering period.

The test for chemical wither advocated by Mr. P. H. Carpenter of the Indian Tea Association was also investigated during the year, and an account of this has already appeared in *The Tea Quarterly*, Vol. I, No. 4, pp. 93, 1928.

D. I. EVANS,
Biochemist.

REPORT OF THE ENTOMOLOGIST.

Advisory:—661 letters were received, and 554 sent out. 198 consignments of specimens were received for report. These included 162 in connection with Tea, 8 each Albizzia and Dadap, 6 Tephrosia, 4 Gliricidia, 3 Grevillea, 2 each Lupin and Red Gum and one each Crotalaria and Georgia Velvet Bean.

Travelling:—36 visits were paid to estates for advisory and experimental purposes.

Address:—At a meeting of the Dickoya District Planters' Association on September 26th, an address was given on "The possible use of parasites for controlling Tea Tortrix."

Assistant:—Mr. D. J. William took up duties as assistant at Mahagalla on August 1st.

TEA.

Leaf Eating Pests.

Tea Tortrix (*Homona coffearia*, Nietn.) :—The parasite described in the last Annual Report as attacking the egg-mass of Tea Tortrix has been identified by the British Museum as *Trichogramma erosicornis*, Westw., a species not previously represented in the collection of the British Museum.

Preliminary experiments in the breeding of this parasite in the egg of *Sitotroga cerealella* (Angoumois Grain Moth) bred from Indian corn were carried out in the Laboratory in Nuwara Eliya in the earlier part of the year. On July 1st, the Entomologist took up quarters in the bungalow on Mahagalla Estate in Maskeliya, where a laboratory for the breeding of *Trichogramma* was fitted up.

The breeding of the parasite has been continued since then, but the results have been disappointing; until December the degree of parasitism fluctuated considerably, and progress was very slow. During December, however, steadier and much improved results were obtained.

When the breeding was commenced in July, as maize infested with *Sitotroga* could not be obtained in quantity, the moths were bred in paddy. Later, experiments were carried out in breeding the parasites in the eggs of *Sitotroga* from Indian corn, but the results on the whole are little better than those obtained latterly with the use of paddy.

The unsatisfactory results obtained in breeding *Trichogramma erosi-cornis* are due, I believe, to the fact that this species probably does not breed readily enough under artificial conditions (where it is forced to reproduce in an egg too small to allow development to its normal size.) I suggest, therefore, that the species *Trichogramma minutum*, Riley, which has been bred successfully in America under artificial conditions, be imported into this country and subjected to breeding trials.

Nettle Grub (mainly *Natada nararia*, Moore) :—Attacks of Nettle Grub have been unusually severe in parts of Uva this year, being more persistent and widespread than formerly. The newly developed tendency of the grubs to attack young tea even before tipping, as reported in the last Annual Report, was again observed. It also appears that the pest is acquiring a certain immunity from the effects of rainfall, and so is enabled to continue its ravages throughout prolonged wet periods.

That Nettle Grub is gradually increasing its range is shown by the fact that it was reported in November, for the first time on record, from the Udapussellawa district. The estate on which it occurred is in the South-East corner of Udapussellawa, so that the pest must have passed over from Badulla.

In September, by arrangement with the Department of Agriculture, the Government Entomologist visited the Nettle Grub infested regions of Uva, and prepared a report on this pest. He advocated that attention should be paid to a line of control that I have advised in the past, namely, the destruction of the cocoons formed by this insect, as the most convenient stage in which the pest may be tackled. It has been found that very large numbers of cocoons may often be collected from the soil at the foot of the bushes as well as on the leaves. A suitable method of dealing with the cocoons has not, so far, been discovered. The application of Nitrolim to the soil has proved a failure.

As far as the destruction of the caterpillars is concerned, calcium cyanide dusted over the bushes proved to be almost entirely without effect, while Nitrolim did not give satisfactory results. Sodium silicofluoride, applied in powder form as a stomach poison was not a success.

A predatory enemy of the Fringed Nettle Grub (*Natada nararia*, Moore) has been found in the form of a Pentatomid bug. The latter is dark brown in colour and from $\frac{1}{2}$ — $\frac{3}{4}$ inch in length, the male being smaller than the female. In attacking its prey, the bug impales one of the grubs on the end of its "beak" (or proboscis) and holds it suspended in mid air while it sucks out the juices of its body.

Bag Worms (*Psychidae*) :—These pests have been particularly prominent this year, and several reports of serious outbreaks have been received from low-country estates.

Clania crameri, Westw., Faggot Worm, has been the most commonly reported species. On one estate in the low-country, 15 acres were attacked, the insects being so plentiful that three or four sacks full were collected and buried daily. The loss of made tea was estimated at 2,000—2,500 lbs. Promptly applied hand-picking by children prevented further damage.

Acanthopsyche subteralbata, Hmps., was reported to have stripped many Albizzia trees and spread to the tea. The attack was directed mainly to the older leaves. In the most badly attacked area the tea was pruned. Lopping of the Albizzia trees drove the insects to the tea, where, to quote the Superintendent, "they swarmed up the pruned branches and ate the bark until we treated them with Brunolinum."

Acanthopsyche (?) *cana*, Hmps., is another small species reported to attack nursery tea plants in Madulsima.

Other bagworms reported from tea were *Chalia doubledayi*, Westw., *Clania variegata*, Snell, *Psyche albipes*, Moore, *Psyche vitrea*, Hmps., and several other species not identified.

It has been observed that outbreaks of bag worms, particularly of the Faggot Worm, tend to occur in fields planted with Albizzias. The insects frequently start on the Albizzias and thence, either when the trees have been stripped of foliage, or as reported in one instance, after heavy rainfall, they leave the Albizzias and commence feeding on the tea. They usually attack only the older leaves of tea, but in severe outbreaks, considerable damage is done to the flush as well. In one instance, bushes recovering from pruning were attacked.

The resistance to chemical treatment displayed by bag worms is illustrated by the following experiments conducted in the laboratory.

The tests were made with caterpillars of a small species of *Acanthopsyche*, a pest of Albizzia. Leaves of Albizzia were first sprayed with water and then dusted with (a) Paris green, and (b) Sodium silicofluoride mixed with four parts and three parts, respectively, of sifted lime. The leaves were then placed in wire gauze cages and the bag worms were introduced. With Paris Green, after one day, 4 per cent and, after two days, 36 per cent were dead. With Sodium silicofluoride, the corresponding figures were 0 and 10 per cent. In contrast, the results for Paris Green in a similar experiment with a small Geometrid caterpillar attacking Albizzia were—after one day 60 per cent. and after two days 88 per cent.

Since bag worms are thus resistant to "stomach" poisons and since a contact spray is out of the question, on account of the protecting bag or case of these insects, emphasis is again laid on the recommendation of hand-collection as the only way of dealing with these pests on tea, without pruning the bushes.

Prodenia litura, F:—Caterpillars of this Noctuid moth were reported from Badulla as the cause of considerable damage to tea newly out of pruning. Both old and young leaves were eaten, but on adjoining fields of old tea the caterpillars ignored the bushes, and confined their attention to the heavy cover of Oxalis. The manager of the affected estate reported the caterpillars, which spread over an area of 70 acres, to be so numerous that hand collection, which was at first attempted, was found to be quite inadequate in dealing with them.

The moth is a night flier. Its eggs have been found on green manure loppings between rows of tea. The caterpillar forms its chrysalis in the soil at the foot of the bush, an inch or two below the surface. Forking of the soil in this position, so as to expose the chrysalides, might prove a profitable line of control.

There are few previous records of *Prodenia litura* attacking tea, and the present instance is the only serious outbreak that has been reported for nearly 30 years.

Agrotis sp.—Caterpillars were received from a Calaha estate with a report of damage to 20 acres of tea four months from pruning. The injury inflicted was not great, only the older leaves being eaten. A few specimens of *Prodenia litura* were included amongst the *Agrotis*.

Lobster Moth (*Stauropus alternus*, Moore):—In one report from the low-country, these caterpillars were found on tea over an area of 100 acres. Hand collection brought them under control in five weeks, but the damage done by this pest and to a certain extent by Tea Tortrix was estimated at 2,500—3,000 lbs. of made tea.

Small Tussock Moth (*Notolophus posticus*, Wlk.):—The hairy caterpillars of this moth have been reported several times on tea. This insect appears to be essentially a pest of dadap, but it frequently descends to the tea when the trees have been stripped. The yellow-brown cocoons are readily seen on the foliage, and since the moth lays her eggs largely on the outside of the cocoon, attention should be paid to the collection of the cocoons.

Taragama dorsalis, Wlk.:—Though usually a pest of dadap, this pest was found attacking tea bushes in a field interplanted with dadaps, from which the caterpillars had evidently migrated. The large dirty-white cocoons of this species are sometimes found attached to tea stems as in the case of the similar dadap pest *Suana concolor* Wlk.

Weevil (*Astycus immunis*, Walk., var *bilineatus* Mshl.):—An attack occurred on a Badulla estate over 25 acres of tea and dadaps; the weevils attacked mainly the latter, but numbers were also found on the bushes, which were “ragged” a good deal, but little damage resulted, since only the older leaves were affected.

Leaf Sucking Pests.

Tea Mites:—Only four reports of mites were received during the first half of the year, but they were much in evidence from August to October.

Red Spider (*Tetranychus bioculatus*, W.M.) was the most commonly reported species. This mite does little damage, usually being found on a few of the older leaves on bushes scattered here and there. But in severe outbreaks considerable defoliation occurs, and the development of the flush is delayed. There is little doubt that when the attack is continued for some time, the yield of leaf is appreciably affected.

Purple mite (*Eriophyes carinatus*, Green) is frequently found to be abundant in fields exposed to the S.W. wind.

Scarlet Mite (*Brevipalpus obovatus*, Donn.)—Experiments to test the effect of shade on Scarlet Mite have been in progress for some time on an estate in the Haputale district. Two shelters have been erected one about 5 ft. high and the other (erected later) about 10 ft. high and covering a greater number of bushes. After a year, when examined during the “mite season”, the bushes beneath the smaller shelter were seen to be fresher and greener than the surrounding bushes and to be appreciably freer from mites. Information regarding the second shelter is not yet available.

Helopeltis antonii, Sign.:—The presence of *Helopeltis* in Ceylon has been recognised for many years. Though at one time it was a serious pest in parts of the tea area, little trouble has been occasioned by it for a consider-

ble time. Laterly, however, it appears to have been more abundant in Morawak Korale, where most, if not all, the estates have been infected this year. The superintendent of one estate in that district has informed me that he has observed *Helopeltis* only in the fields of poorer jat, all of which show signs of infestation. The pest is most noticeable at 9—18 months from pruning (the pruning cycle there is 18 months). Dry and windy weather during the S. W. monsoon is most favourable to its occurrence, and it disappears with prolonged rainfall. Considerable loss of crop is reported.

***Callicratides rama*, Kirby** :—A green Capsid bug commonly found singly on tea bushes. Bugs of this species were included in a consignment of *Helopeltis* sent in from Morawak Korale, and comprised at least one-third of the insects received. They were said to occur indiscriminately with the *Helopeltis*.

***Ricania* spp.** (Fulgoroideae) :—*Ricania speculum* Walk., a bug with broad brown and white wings, much like a moth in appearance, was reported to attack the older leaves of bushes that had been recently cut across. The insects were found in all stages, mainly on the undersides of the leaves; the eggs were discovered laid in rows of slits in the back of the midrib and side veins.

Ricania fenestrata, Fabr., which closely resembles *R. speculum*, was received from another estate where it was said to be present in clusters on the shoots. Included with these were a few specimens of a pale green Fulgorid, *Flata ocellata* Fabr. The shoots received with these insects showed the spotting of the leaves typical of bug damage.

Tea Aphis (*Toxoptera aurantii*, Boy.) :—This pest which is frequently found on almost every bush in a field of tea recovering from pruning, is controlled largely by natural enemies. The commonest of these are the grubs of Syrphid flies. In one cigarette tin full of infested flush received from an estate, 57 flies in various stages, comprising at least four different species, were discovered.

Other enemies include the larvae of Hemerobiid flies, and the larvae and adults of Coccinellids (lady-bird beetles).

Miscellaneous :—Other leaf-attacking insects that have been reported are Red Slug (*Heterusia cingala*, Moore), Tea Leaf Roller (*Gracilaria theivora* Wlsm.), Tea Leaf Miner (*Ocinis theae*, Bigot), Green Bug, (*Coccus viridis*, Green), Brown Bug (*Saissetia hemisphaerica*, Targ.), and *Lecanium* sp.

Stem-attacking Pests.

Cutworm (*Agrotis ypsilon*, Rott., etc.) :—In tea nurseries, Cutworm can be readily dealt with in a variety of ways. By far the most effective is the use of a poison bait, as described in *The Tea Quarterly* Vol. I, No. I, p. 21.

Experiments with poison baits have been conducted in several vegetable gardens. In one case, Paris Green and Sodium silicofluoride were tested separately as the toxic agents. Each substance was used in two strengths, (a) according to the formula described (*loc. cit.*) and (b) with double the quantity of poison. The results of these experiments have been satisfactory in every case. In from one to three days, the daily nipping off the young plants ceased altogether, and nothing further was seen of the grubs. The

effect appears to last for some time—in the case of quickly growing garden plants often until the plants have outgrown the susceptible stage. But, in the case of plants of slower growth, such as tea, it may be necessary to repeat the application of poison baits.

In nurseries, which are protected from the incursion of dogs, fowls and children, Paris green may be used without fear. But, if any hesitation is felt regarding the use of an arsenical, sodium silicofluoride should be substituted; this substance, it is believed, will give sufficiently good results.

The worst feature of Cutworm attack is the damage that it does in clearings, where both basket plants and those from seed at stake have been attacked. According to one report, 25 per cent. of the plants from seed-at-stake in a 15 acre clearing were destroyed.

Although it is believed that such attacks could be successfully combatted by the use of poison baits, a natural reluctance is expressed by planters to placing the poison out in the field. Sodium silicofluoride is therefore recommended for this purpose. If there is a reluctance to the spreading of even this substance in the open, I can see no reason why in dry weather the bait should not be covered with a handful of earth after being placed at the base of the plant. In this way it would not be exposed, and it seems reasonable to expect that its effect would not be materially lessened.

Miscellaneous:—Red Borer (*Zeuzera coffeae*, Nietn.), Shot hole Borer (*Xyleborus formicatus*, Eichh.) and Tea Termites (*Calotermes spp.*) have also been reported attacking tea stems.

Root-attacking Pests.

White Grub (*Anomala spp.*, etc.) :—Cockchafer grubs have been reported as pests of both nurseries and clearings. Three to four year old plants in a clearing of 60 acres were attacked by a large species, which killed nearly 2,500 plants. Forking practically cleared the soil of the grubs, but it was then found that they were present in huge numbers at the roots of *Paspalum* grass planted on adjacent road side banks. All the *Paspalum* had to be rooted out and the grubs burnt. This occurrence of White Grub in connection with *Paspalum* is worthy of note.

A tea nursery on another estate suffered a loss of 25 per cent. of the plants in three weeks.

When a plant is attacked by White Grub, the leaves first wilt, then turn brown and drop off; the death of the plant quickly follows. If the plant be pulled up, it will be found that the tap root has been gnawed right through a few inches below ground level. In the clearing referred to above, this occurred at 4—6 inches beneath the soil level.

There is no doubt that the incidence of White Grub is often due to the previous application of cattle manure, or the fact that the infested area was at one time a grazing ground for cattle. The clearing above-mentioned had previously been used for the grazing of buffalo. Another tea nursery, from which White Grub was reported, had been treated with cattle manure a few months before.

The control of White Grubs in clearings is a difficult matter. Plants seen to be affected should be pulled out at once, and the grubs at the root dug up and destroyed. Forking of the soil around the plants serves to expose the

grubs. On nursery beds, some relief might be obtained by the use of a solution of Jeyes' fluid, watered over the beds, but this method has not yet been tested out.

Eelworm (*Heterodera radicola*, Greeff.):—A nursery in Lunugala was reported to be badly affected by Eelworm. On investigation, it was found that the plants in the upper end of the nursery were decimated and that the survivors were stunted and sickly in appearance.

Experiments in the application of 1 per cent. solutions of formalin and phenol produced negative results. A number of beds, however, contained plants of normal growth, interspersed with infested plants. On my suggestion, all sickly plants in these beds were pulled up and burnt, a trench 1 foot deep and 3 inches wide was dug around the beds and packed with lime, and finally the beds were said to be coming on well, and to show no further signs of Eelworm.

Ants:—A species of small red-brown ant, not unlike a termite in appearance, was believed to be attacking 2½ year old plants in a clearing. The damage took the form of an injury to the cortex of the stem just below soil level, which produced a ringing effect similar to that caused by wind.

A young tree tomato plant was received later showing a similar ringing of the stem and a thickening of the root cortex above the ringing. On this plant the ants were present in considerable numbers, feeding on the cortex, and boring right into the tissues of the plant. Experiments in the inoculation of young tea plants in pots produced negative results. Since the same ants have been observed also at the roots of French Beans, it is not impossible that they may attack young tea plants. I shall be very glad if superintendents of estates can supply me with further observations in this connection.

Tainting Tests:—The possible tainting of the manufactured tea by the use of insecticides applied to the bushes has received little attention in the past, although of importance, as it is evident that substance which produce definite tainting cannot be used to control insects on bushes in bearing, however efficient their insecticidal action may be. The experiments commenced last year were therefore continued, a field on the same estate being utilised for this purpose.

In these experiments the bushes were treated immediately after being plucked. The period elapsing between treatment and the plucking of the treated leaf was 8—9 days. The leaf was withered in the usual way, and then rolled by hand on a wooden board. Precautions were taken to prevent the taint in one sample from affecting the next sample, by washing the board thoroughly after each rolling; the cooly who carried out the work was made to wash his hands at the same time.

The first tests were carried out in 1927 with sodium silicofluoride in spray form (1 lb. to 20 gallons of water), a commercial brand of lime sulphur (1.24 solution) and a kerosene-flour emulsion (containing 2½ per cent. of kerosene). Three samples of made tea from the bushes treated with each of the first two insecticides together with one control from untreated leaf were submitted for report to a firm of brokers. Of the kerosene-flour, two samples and two controls were submitted. The reports were as follows:—Lime sulphur: two samples distinctly tainted, one slightly; control: "very

nearly pure." Sodium silicofluoride: two samples distinctly tainted, one slightly; control: slightly tainted. Kerosene-flour: "slight suspicion of taint" in one of the treated samples,—“none of the teas are pure.”

This year a more extensive series of trials were carried out, using sodium silicofluoride, flowers of sulphur, kerosene-flour emulsion and calcium cyanide "A" dust. For each treatment 2 plots of 20 bushes each were employed, and from these four samples were submitted for report. Six samples of untreated leaf from the same field were sent as controls.

TABLE I.

Insecticide.		Sample. 1	Sample. 2	Sample. 3	Sample. 4	Sample. 5	Sample. 6
Control (untreated)	..	T	ST	ST	Nil	Nil	Nil
Sulphur (dust)	...	T	T	T	T	—	—
Sulphur. Equal amount normal leaf	...	T	T	T	ST	—	—
Sulphur. Twice amount normal leaf	...	T	T	T	ST	—	—
Calcium cyanide "A" (dust)	...	T	T	T	T	—	—
Calcium Cyanide. Equal amount normal leaf	...	T	T	T	ST	—	—
Sodium silicofluoride (dust)	...	T	ST	ST	ST	—	—
Sodium Silico fluoride. Equal amount normal leaf	..	T	ST	ST	Nil	—	—
Sodium Twice amount normal leaf	...	T	T	T	ST	—	—
Kerosene-flour (spray)	...	T	ST	ST	ST	—	—
Kerosene-flour Equal amount normal leaf	...	ST	ST	ST	ST	—	—
Kerosene-flour Twice amount normal leaf	...	T	ST	ST	ST	—	—

Note:— T indicates considerable tainting effect.
ST " " slight tainting.

The results shown in Table 1 are not very conclusive, but they provide an indication of the relative effects produced by the various substances employed. It will be seen that the greatest tainting effect is reported from the samples treated with sulphur and with calcium cyanide. Sodium silicofluoride apparently causes considerably less tainting, while the kerosene-flour emulsion, as in the 1927 tests, produces the least effect.

The production of tainting in the manufactured leaf, and the degree to which such tainting occurs must depend largely on the proportion of treated leaf that is present in the roller. In order to test this assumption, samples were sent for report in which the treated leaf had been "diluted" with (a) an equal amount, and (b) twice the amount of untreated leaf. These experiments produced results that are disappointing, as differing little from those obtained from samples of "undiluted" leaf. At the same time it will be noticed that the addition of a quantity of untreated leaf (with one exception) results in a decrease in the degree of tainting produced,

The results given in the table show that of all the samples tested only four, including only one of the treated samples, showed no signs of tainting. Of the control samples, three of the six are stated to show tainting, one very distinctly. Since tainting is reported even in untreated samples, it is evident that some factor apart from the chemical treatment is present which tends to produce tainting. The probable explanation is that in spite of the precautions taken to carry out the manufacture under the most sanitary conditions, the process of hand-rolling sometimes imparts a noticeable taint to the sample.

Present conclusions regarding the relative effects of the substances tested are as follows:—lime sulphur, flowers of sulphur, sodium silicofluoride (spray) and calcium cyanide give very noticeable tainting; sodium silicofluoride (dust) less definite, and kerosene-flour emulsion only slight tainting.

For conclusive results, these experiments will have to be repeated under more suitable conditions, the rolling of the leaf being done in a miniature roller. In order to obtain more definite results in "dilution" with untreated leaf, it will be necessary to use a greater proportion of the latter, e.g. four and ten times the quantity of treated leaf.

ALBIZZIA.

Macaria pluviana, Fabr.:—The caterpillars of this Geometrid moth were found attacking Albizzia seedlings. Considerable defoliation was caused, and a number of plants died as the result of the attack. The eggs are laid mainly on the young shoots, and the chrysalis is formed in the soil.

Experiments were carried out in the control of this pest by the use of poisonous dusts and sprays. Spraying with Paris Green gave only moderate success, but good results were obtained in the laboratory with a dusting mixture composed of one part of Paris Green to four of sifted lime. Since, according to the Government Entomologist, there is only one previous record of *Macaria pluviana* as a pest of cultivated plants in Ceylon, a separate account of this insect will be published in the Tea Quarterly.

Terias hecabe, L.:—This butterfly which differs slightly from the commoner *Terias silhetana*, Wallace, was taken on Albizzia seedlings. Two marked distinctions are found between these species. In *T. silhetana* the head of the caterpillar is black; in *T. hecabe*, it is green. The chrysalis of *T. silhetana* turns from green to black, while that of *T. hecabe* remains green.

Spirama retorta, Cram.:—The caterpillar of this Geometrid is very long and narrow, nearly black when young, but changing to brown when older. It has been found to attack Albizzia seedlings.

White Grub was found to destroy young plants in a clearing.

Bag Worms:—The following species were reported attacking Albizzia: *Acanthopsyche subteralbata*, Hmps., *Clania crameri*, Westw., *Psyche albipes*, Moore, and *Psyche vitrea*, Hmps.

BOGA MEDELOA (*Tephrosia candida*.)

Mealy Bug (*Pseudococcus* spp.) is certainly the most important and universal pest of *Tephrosia*, and every year numerous outbreaks are reported. Control measures should take the form of immediate lopping off and

burning of all affected branches, or, if necessary, destruction of the entire plant, in order to prevent, as far as possible, the spread of the insect. But, it must be realised that nothing can be done to prevent the recurrence of Mealy Bug, since it is a common pest of *Gliricidia* and many other plants.

Cutworm (*Agrotis* sp.):—Boga plants sown to form contour hedges in a clearing were destroyed by Cutworm at the same time as the young tea plants growing there.

CROTALARIA SPP.

Argina syringa, Koll.:—The caterpillars of this Arctiid moth have proved disastrous to the growth of *Crotalaria longipes* in the field. Nearly every plant on one estate was covered with caterpillars, while on some the foliage was destroyed to such an extent as to leave little but the tip of each shoot. The leaf was first skeletonized and then often entirely consumed. Pods were attacked while young so that they never developed far. Nursery plants were also attacked.

It is believed that early spraying—as soon as the caterpillars are seen on the plants—will control this pest. Paris Green at the rate of 1 lb. to 50 gallons water is recommended, but if there is any objection to the use of this substance, sodium silicofluoride mixed with three times its weight of sifted lime should be dusted over the plants.

The round yellow eggs are laid singly on the leaves, chiefly on the undersides. The caterpillars are black marked with greyish white dashes, and clothed with long sparse grey hairs, the head being red. Pupation takes place in a loose cocoon which is found usually at the apex of the shoots; the chrysalis is yellow brown with black spots and dashes.

Argina argus, Cram.:—A species similar to the above has been reported to attack *Crotalaria Brownei*. A few caterpillars of *A. argus* were found amongst those of *A. syringa* on *Crotalaria longipes*.

Pod-boring Caterpillars:—These have been found to destroy the seeds of *Crotalaria usaramoensis*.

DADAP (*Erythrina lithosperma* Bl.)

Small Tussock Moth (*Notolophos posticus*, Wlk.):—Several outbreaks of these caterpillars have been reported on both old and young dadap trees, sometimes doing considerable damage.

Astycus immunis, Walk. var. **bilincatus**, Mshll.:—Beetles of this species were reported attacking 25 acres of dadaps and tea. The young trees growing from stumps were the most severely injured.

Miscellaneous:—A number of different caterpillars have been sent in as attacking dadap stumps over about three acres on an up-country estate. These included *Taragama dorsalis*, Wlk. the large green caterpillars of a Sphingid moth, and the caterpillars of *Calpe emarginata*, Fabr., which are deep black with red and yellow spots.

GEORGIA VELVET BEAN (*Mucuna* sp.)

Mealy Bug (*Pseudococcus* sp.) was reported on plants in a nursery. The bugs were confined mainly to the stems, and little damage was done. This is the first record of Mealy Bug on Georgia Velvet Bean in Ceylon.

GLIRICIDIA MACULATA, A.B. and K.

Albizzia caterpillar (*Terias silhetana* Wallace) was found to attack isolated trees amidst Albizzias already infested with the caterpillars.

GREVILLEA.

Cutworm (*Agrotis ypsilon*, Rott.) :—On one estate several beds of seedlings were almost entirely destroyed.

Miscellaneous :—Two species of small green Pierid caterpillars, assisted by the larvae of *Euxoa segetum*, Schiff., caused a good deal of damage amongst seedlings, nipping off either the top of the plant or some of the terminal leaves. Most of the plants died as the result of the attack, the product of at least 1 lb. of seed being lost. The Superintendent of the estate informed me that watering the beds with lime water and tobacco water had little effect on the insects. Spraying with Paris Green would probably have proved effective.

Eelworm (*Heterodera radiculicola*, Greeff) has been found to attack seedlings, which died out in patches. The remaining plants were saved by cutting out the portions of the beds containing infested plants.

RED GUM (*Eucalyptus robusta* Sm.).

Small Tussock Moth (*Notolophus posticus*, Wlk.) :—Considerable damage to seedlings has been caused by these caterpillars; the plants were in some cases completely stripped of every leaf. About 30 per cent of the seedlings died from this defoliation.

Trabala vishnu, Lef. :—The large hairy caterpillars of this lasiocampid moth were found to defoliate gum trees. Young trees are evidently preferred.

The caterpillars when full grown are of a grey colour with a pinkish tinge in their thickly felted hairs. Pupation takes place inside a grey, felt like cocoon curiously shaped like the humps of a camel, which is suspended from a twig. The male moth is of a beautiful apple green colour, while the female is larger and greenish yellow with a large square cinnamon coloured patch on the forewing. The eggs are round and lead-grey in colour, laid always in a straight double row, and covered with hairs from the female's body. They are probably laid on the stem of the tree. This outbreak is worthy of note on account of the fact that *Trabala vishnu* has been recorded on tea in Indo-China.

INSECTICIDES.

Experiments were carried out to determine the relative toxicities of Paris Green, lead arsenate and sodium silicofluoride. Nettle Grub (*Natada nararia*, Moore) and a weevil *Astycus immunis*, Walk var., *bilineatus* Mshll. were used as test media.

Tea leaves sprayed with water and then dusted with the insecticide were placed in glass cylinders, covered at the ends with muslin, and the insects introduced. Control cages were kept in which the leaves were sprayed with water only. Results were calculated from counts of living and dead.

From these experiments, Paris Green showed itself to be considerably more toxic than either lead arsenate or sodium silicofluoride. With Paris Green, after four days, practically 100 per cent of both weevils and caterpillars were dead. This substance also acted far more quickly than the other two. Lead arsenate had a quicker action than sodium silicofluoride on both insects, but the toxic effect produced by both substances was much the same after four days.

Paris Green, therefore, should be used for spraying or dusting in preference to the other two insecticides where feasible, such as in nurseries or for young plants in clearings. It has the additional advantage of being coloured, which is an asset when it is necessary to mix it with another substance such as lime. Thorough mixing is difficult to judge when the two powders are of the same colour, *e.g.*, lime and lead arsenate, which are white.

A series of tests with sundry insecticides, standard and proprietary, has been begun, using Tea Tortrix larvae as test subjects. These experiments are not yet complete. The substances under trial to date are: a colloidal sulphur contact insecticide, a pyrethrum extract, Nitrolim, Hycol and Izal.

S. STUART LIGHT,
Entomologist.

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TEA RESEARCH INSTITUTE OF CEYLON.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1928.

EXPENDITURE		Rs.	Cts.	INCOME		Rs.	Cts.
To Expenditure as per attached Statement	...	119,978	72	By Tea Cess Collections	...	236,193	85
" Balance, being excess of Income over Expenditure	...	130,065	27	" Interest	...	13,850	14
						Rs. 250,043	99

BALANCE SHEET AS AT 31st DECEMBER 1928.

LIABILITIES	Rs.	Cts.
Tea Research Funds Account as at 31st December, 1927 ...	Rs. 278,591·14	
Excess of Income over Expenditure for the year 1928	<u>Rs. 130,065·27</u>	
	408,656	41
	<u>Rs. 408,656</u>	<u>41</u>

ASSETS	Rs.	Cts.
Ceylon Association in London	4,127	08
Accrued Interest	5,318	55
Fixed Deposit Hongkong & Shanghai Bank 4½%	170,000	00
Do Mercantile Bank, Kandy, 4%	200,000	00
Current Account, National Bank, Colombo	28,874	26
Do Nuwara Eliya	230	76
Cash in hand	91	67
Stamps	14	09
	<u>Rs. 408,656</u>	<u>41</u>

Audited and found correct.

(Signed) FORD, RHODES, THORNTON & Co.,

Colombo, 7th February, 1929.

Chartered Accountants.

THE RESEARCH INSTITUTE OF CEYLON.

EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1928.

Administration of the Board:—

	Rs.	cts.	Rs.	cts.
Planters' Association of Ceylon	2,400	00		
Secretary	2,400	00		
Travelling Expenses of the Board	1,907	18		
Postages	162	39		
Stationery	880	51		
Advertising	769	31		
Telegrams, Commissions, etc.	271	78		
Legal Charges	12	00		
Auditors' Fee and Expense	279	41		
C. L. T. A. Hire of Hall	15	00		
			9,536	73

Personal Emoluments of Scientific Staff:—

Director	22,500	00		
Mycologist	15,556	84		
Bio-Chemist	11,460	00		
Agricultural Chemist	11,522	57		
Entomologist	9,970	94		
House Allowances	9,880	35		
			80,890	70

Laboratories:—

Assistants	1,365	00		
Cooly	271	86		
Rent and Taxes	3,114	10		
Insurance	42	50		
Equipment	7,362	00		
Furniture and Alterations	1,133	23		
Library	1,422	95		
Publications	1,981	20		
Assistants Travelling Expenses	26	08		
			16,718	92
			621	68

Field and Factory Experiments

Laboratory Offices:—

Clerk	1,050	00		
Peon	513	21		
Stationery	479	81		
Postages	201	56		
Telephone Rent	180	00		
			2,424	58

Travelling Expenses of Staff:—

Office Expenses	1,079	27		
Insurance of Car	197	10		
Taxes	40	00		
Driver's Wages	1,062	00		
Driver's Batta	177	50		
Running Expenses	1,239	63		
			3,795	50

Contingencies:—

Incidentals	949	98		
Ceylon Planters' Provident Society	3,293	43		
Passages	1,747	20		
			5,990	61

Balance:—

Being excess of Income over Expenditure for the 12 months ended 31 December, 1928.	130,065	27		
	Rs.	250,043	99	

Audited and found correct.

(Signed) FORD, RHODES, THORNTON & CO.,

Colombo, 7th February, 1929,

Chartered Accountants.

